RĪGAS STRADIŅA UNIVERSITĀTE

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THE SEXUAL DIMORPHISM AND AGE-RELATED CHANGES OF THE LESSER PELVIS IN HUMAN

Summary of Doctoral Thesis
to obtain the degree of a Doctor of Medicine

Speciality – Morphology

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1. INTRODUCTION

Humans are constantly adapting to the environmental changes, which reflect in their anatomy. Adaptation to evolutionary challenges affected the shape of a human pelvis and became the reason for its sexual differences. Having become a support for the upper part of the body, the human pelvis acquired the central place in the body balance regulatory system.

Studies, based on the osteological material, demonstrate differences between male and female pelvis, which are exposed in the means of pelvic parameters, their variances and relationships between sizes of the lesser pelvis and general anthropometric measures (*Tague*, 1989; 1992; 2000; *Correia et al.*, 2005; *Peleg et al.*, 2007; *Kurki*, 2007; 2011; *Ridgeway et al.*, 2011). Observed inconsistency between the previous study data and theoretical considerations refer to differences of variance of lesser pelvis parameters between sexes. From the theoretical point of view, additional adaptation of female pelvis to parturition during the human evolution can cause lower variability of pelvic parameters than in males (*Tague*, 1989). This effect is described during an assessing of sexual dimorphism of pelvis using the visual scale (*Meindl et al.*, 1985), while the metric studies demonstrate that some pelvic measures in females demonstrate higher variance than those in males (*Tague*, 1989; 1992). Taking into account that the most pronounced sexual differences in pelvic parameters have been found at the level of ischial spines (*Tague*, 1992; *Walrath and Glanz*, 1996), it is possible to expect that a parameter with a lower variance is located at this level of pelvic cavity.

Clinical studies show that specificity of the pelvic cavity impacts the labour outcomes (*Zaretsky et al.*, 2005; *Stalberg et al.*, 2006; *Lenhard et al.*, 2010) and development of pelvic floor diseases (*Nguyen et al.*, 2000; *Handa et al.*, 2003; *Lazarevski*, 2004; *Xu et al.*, 2011). Lately the attention has grown also to the male pelvic architecture (*Salerno et al.*, 2006; *Hong et al.*, 2007;

von Bodman et al., 2010). It updates the question on the closeness of the interrelationship of pelvic parameters and prediction of clinically important parameters of the pelvic cavity by the parameters of the greater pelvis. In previous studies the correlation analysis was done in female groups (*Yong and Ince*, 1940; *Ridgeway et al*., 2011), but the data on pelvic parameter interrelationship for males have not been presented.

The age-related change of the pelvic cavity is the theme little presented in the scientific literature. Like the influential factors affecting the bony pelvic system there are mentioned the age-related changes in sacroiliac joint (*Peleg et al*., 2007), the disruption of the force balance system under the influence of vertical load, and a higher load on the pelvic floor in females during pregnancy and the labour (*Lazarevski*, 2004). However, the previous studies are focused on the changes of the pelvic angles (*Amonoo-Kuofi*, 1992; *Lazarevski*, 2004; *Peleg et al*., 2007; *Mac-Thiong et al.*, 2011), while changes in the linear parameters of the pelvic cavity during aging have not been sufficiently studied. Considering the sexual dimorphism of the pelvis, it is possible to hypothesize different aging tendencies for pelvic parameters in females and males.

The anthropological issues mentioned above emphasize the necessity to investigate the pelvis in live individuals. The opportunity to reconstruct the human pelvic structure including the individual width of pelvic joints (*Balleyguier et al*., 2003) is an essential difference of the current study from many previous anthropological studies which had been performed on skeletal collections.

Aim of study: To assess sexual dimorphism of the lesser pelvis and to explore age-related changes of pelvic architecture.

Hypotheses of study:

1. A parameter of pelvic cavity with a lower variance in females than in males is placed at the level of ischial spines.

2. Patterns of age-related changes of pelvic parameters differ in females and males.

Objectives of study:

1. To detect sagittal and transverse parameters of the lesser pelvis at four levels of the pelvic cavity, additional parameters, and pelvic angles in the sample of live humans.
2. To assess sexual dimorphism in means and variances of the pelvic dimensions and indexes.
3. To evaluate the level of correlation between parameters of the narrowest pelvic place and the greater pelvis and other dimensions of the pelvic cavity. To assess sexual dimorphism of these correlations.
4. To determine the regression of the pelvic dimensions on age and gender and to assess the aging tendencies in females and males.

Novelty of study:

- The study presents new aspects of sexual dimorphism, which refers to variance of measures of the lesser pelvis. A parameter has been identified in which variance in females is lower than in males.
- The results demonstrate the level of the relationship between transverse diameters of the pelvic cavity and the greater pelvis transverse diameters in both sexes which add to the understanding on these connections in males and specify the possibilities of prediction of the narrowest place of the pelvic cavity.
- The age-related tendencies have been revealed for diameters of the pelvic cavity.
- The results show, that the transverse diameter of the pelvic cavity at the level of the hip joint centers does not depend on age.

Significance of study

Results of the doctoral thesis demonstrate that the narrowest diameters of the pelvic cavity (at the level of ischial spines) depend on the diameters of the lesser pelvis at other levels and are considerably lesser connected with transverse diameters of the greater pelvis. A slight predictive significance refers only to one of the three measures of the greater pelvis – the distance between two greater trochanters (*distantia intertrochanterica*). It confirms, that the external pelvimetry has little importance in prediction of the narrowest pelvic cavity diameters and, indirectly, also in prediction of prolongated labour. Sagittal and transverse diameters at the level of ischial spines (*spina ischiadica*) do not depend on the length of diagonal conjugate (*conjugata diagonalis*), which can be determined during vaginal examination.

In males, the measures of the greater pelvis also do not predict the narrowing of the pelvic cavity. Thus, these measures cannot be effectively used in estimation of possible complications prior to the prostatectomy and rectal surgery or in choosing the adequate size of instruments.

The results also show that the pelvic bone system is changing with age. However, the distance between the centers of hip joints does not change despite the transformation of the pelvic cavity shape. Taking into account that the distance between acetabular centers does not depend on age, but depend on sex, this pelvic parameter can be recommended for identification of sex in forensic medicine. Results of the thesis also suggest that age can be a factor increasing the risk of pelvic floor disorders through affecting the pelvic bone system.

Structure of doctoral thesis

The doctoral thesis consists of five sections: Literature survey, Materials and Methods, Results, Discussion, and Conclusions. The literature survey deals with general concepts, which comprise the structure of the pelvis, manifestations of sexual dimorphism of the pelvis and theories of its development. The view on the age-related changes of the pelvic cavity and the choice of the methods of measurement are justified. The thesis is based on 177 literature sources. The work contains 39 pictures and 13 tables.

2. MATERIALS AND METHODS

2.1. Study subjects

A research sample was formed of the subjects who had undergone the abdominal and lesser pelvis computer tomography (CT) examination at Riga Eastern Clinical University Hospital „Gaiļezers" Radiology Unit in the period from November 2009 till November 2010. In order to use the archive materials of the Radiology Unit for doing retrospective measurements, the permission was received from Rīga Stradiņš University Ethics Committee.

The initial sample consisted of 427 subjects (230 females and 197 males). The main indications for the computer tomography examination of the abdominal cavity were the abdominal pain and the inflammatory processes in the abdomen or in the lesser pelvis. This sample included CT pictures of the abdomen, which fully showed the pelvis with lumbar vertebrae. Following exclusion criteria were used: visible bone fractures, a visually decreased bone mass, the pronounced curvatures of the vertebral column in the frontal plane, and pictures, which were taken after the acquired polytraumata.

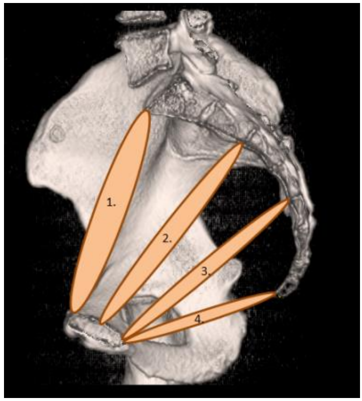
The female and the male samples were formed considering the percentage of females and males in the age groups in Latvian population in 2009 (*Centrālais statistikas birojs*, *2009*), in order to approximate the proportion of age and sex to the population indicators. However, later there were excluded 35 cases with lumbarisation and sacralisation processes from the statistical analysis. As a result, the final sample included 392 adults. From them 211 were females at the age from 18 till 84 years of age (mean age was 48 years ± 18) and 181 males at the age from 18 till 82 years of age (mean age for men was 43 years ± 16). The total number of females and males in the groups was sufficient in order to perform a linear regression analysis.

2.2. Measures

Abdominal or pelvic examination was performed by a scanner (GE Medical Systems Light Speed) with scanning parameters established at 120 kV, 150 – 500 mA, rotation time 0.5 s, 16 spirals, with slice thickness at 1.25 mm. The pelvimetry was performed retrospectively on 3D workstation (Adwantage Workstation for Diagnostic Imaging, GE Healthcare) using multiplanar reconstruction and volume-rendered images. The pelvimetry was performed on pelvic images in coronal and sagittal view. Assessed in a subsample of 23 participants, the intra-rater reliability after two weeks varied from .92 to .99.

Sagittal and transverse diameters of the lesser pelvis were evaluated in four slope axial planes at the following levels (Picture 2.1):

1. Inlet plane – a slope axial plane at the level of the inlet. The plane includes the superior border of the pubic symphysis (*symphysis pubica*) and the promotorium of the sacrum (*promontorium*).
2. Superior midplane (Midplane 1) – a slope axial plane at the level of acetabular centers. The plane passes through the posterior midpoint of the pubic symphysis, centers of acetabulum (*acetabulum*) and joint between 2nd and 3rd sacral vertebrae.
3. Inferior midplane (Midplane 2) – a slope axial plane at the level of ischial spines. The plane passes through the inferior border of the pubic symphysis, ischial spines (*spina ischiadica*) and joint between 4th and 5th sacral vertebrae.
4. Outlet plane – a slope axial plane at the level of the outlet. The plane includes the inferior border of the pubic symphysis, ischial tuberosities (*tuber ischiadicum*) and tip of the coccyx.



Picture 2.1 Schematic representation of levels of pelvic cavity (a 3D reconstruction in a sagittal plane)

1 – Inlet plane; 2 – Midplane 1; 3 – Midplane 2; 4 – Outlet plane

Linear parameters of the pelvic cavity and pelvic angles were measured by analogy with other three-dimensional CT studies (*Lenhard et al*., 2009; 2010; *Ergun et al*., 2010) and osteometric studies (*Tague*, 1989; *Peleg et al*. 2007; *Kurki*, 2011).

Transverse parameters of the greater and the lesser pelvis an one pelvic angle were measured on threedimensional pelvic reconstruction in coronal plane:

1. ***Distantia intercristalis*** – the widest distance between iliac crests.
2. ***Distantia interspinosa*** – the widest distance between two anterior superior iliac spines.
3. ***Distantia intertrochanterica*** – the widest distance between two greater trochanters.
4. **Transverse diameter of the inlet** – the widest distance between the arcuate lines.
5. ***Angulus subpubicus*** – the subpubic angle, the angle formed by two inferior pubic ramus.

6. **Transverse diameter of the superior midplane** (transverse diameter of Midplane 1) – the distance between the centers of acetabulums. For this measurement the view was additionally cut in frontal direction.
7. **Transverse diameter of the inferior midplane** (transverse diameter of Midplane 2) – the narrowest distance between two ischial spines.
8. **Transverse diameter of the outlet** – the widest distance between inner margins of the ischial tuberosities.

Sagittal pelvic measures and three pelvic angles were measured on threedimensional pelvic reconstruction in sagittal plane:

9. **Sagittal diameter of the inlet** – the distance between anterosuperior border of the pubic symphysis and the promontory of the sacrum (the anatomical conjugate).
10. **Sagittal diameter of the superior midplane** (sagittal diameter of Midplane 1 or sagittal diameter at the level of acetabular centers) – the distance between the posterior midpoint of pubic symphysis and the anterior point between the second and the third sacral vertebrae.
11. **Sagittal diameter of the inferior midplane** (sagittal diameter of Midplane 2 or sagittal diameter at the level of ischial spines) – the distance between the inferior border of the pubic symphysis and the anterior point between the fourth and the fifth sacral vertebrae.
12. **Sagittal diameter of the outlet** – the distance between the inferior border of the pubic symphysis and the tip of the coccyx.
13. ***Conjugata diagonalis*** – the diagonal conjugate, the distance between the inferior border of the pubic symphysis and the promontory of the sacrum.
14. **Additional sagittal diameter at the level S2-S3** – the distance between the inferior border of the pubic symphysis and the anterior point between the second and the third sacral vertebrae.

15. **Sacral slope** – the angle between the superior surface of the first sacral vertebra and a horizontal plane.
16. **Sacral anatomical orientation angle** (SAO) – the angle between the intersection of a line running parallel the superior surface of the sacrum and a line running between the anterior superior iliac spine and the anterior superior edge of the symphysis pubis (*Peleg et al.,* 2007).
17. **Pelvic inclination** – the angle between the pelvic inlet and a horizontal plane (*Lazarevski*, 2004).

    In addition, the transverse diameter of the thorax was detected on superior-anterior view:
18. **Transverse diameter of the thorax** – the widest distance between 10th ribs.

In accordance with *Young and Ince*, 1940, four indexes of the pelvic planes were calculated in order to assess proportions of the lesser pelvis:

Index = (Sagittal diameter) : (Transverse diameter)

An index represents shape of the plane at selected level. When an index is lesser than 1.00, the plane is transverse-oval. When an index is greater than 1.00, the plane is sagittal-oval.

In accordance with a formula suggested by *Tague* (1989; 1992), a coefficient of sexual dimorphism was evaluated for each pelvic diameter and index:

Coefficient of dimorphism = (Female measure x 100) : (Male measure)

The coefficient greater than 100 demonstrates an extent to which a mean in the female sample is greater than a mean in the male sample. When a coefficient is equal to 100, sexual dimorphism is not presented. In the case of a coefficient lower than 100, mean in males is greater than in females.

2.3. Statistical methods of data analysis

Data analysis was performed with IBM SPSS 19.0 program. Normality of a distribution was tested through Kolmogorov-Smirnov's test with Lilliefors correction of significance. Central tendency was evaluated by means. Dispersion of measures was represented by standard deviation and variance. Student's t test for independent samples was used in order to evaluate differences of means between males and females. Levene's test evaluated equality of variances. Interrelations among measures were evaluated by Pearson correlation coefficient. Correlation coefficients were compared trough Fisher's z test. A multivariate linear regression was used in order to evaluate dependence of pelvic measures on age and sex. An age-sex interaction was evaluated by othogonalized residuals allowing to exclude from analysis a common part of their variance. Predictors of the narrowest diameters in the pelvic cavity were evaluated through sequential linear regression including groups of pelvic measures as independent variables.

3. RESULTS

3.1. Sexual dimorphism of the pelvis

Statistical tests were selected on the basis of normal data distribution. The normality of distribution was revealed by Kolmogorov-Smirnov's test with Lilliefors correction of significance for pelvic measures in the female and in the male samples. For any subsequent analysis, a parametric test was chosen.

In order to evaluate sexual dimorphism, means and variances of each pelvic measure were compared between females and males (Table 3.1).

Table 3.1

Descriptive statistics, coefficients of sexual dimorphism, and tests for differences of means and variances of lesser pelvis parameters and additional measures

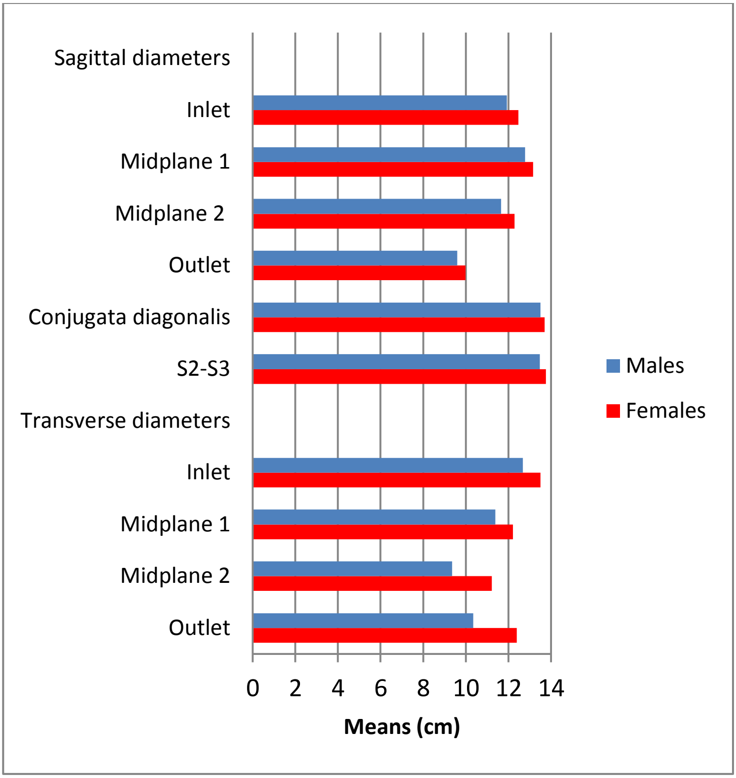
Parameters	Females (n=211) M (SD)	Males (n=181) M (SD)	Coefficient of dimorphism	Stjudent's *t* test	Levene's test
Transverse diameters					
Inlet	13.50 (0.85)	12.68 (0.70)	106.47	10.31***	5.06*
Midplane 1	12.21 (0.83)	11.38 (0.72)	107.29	10.37***	2.72
Midplane 2	11.22 (0.92)	9.36 (0.84)	119.87	20.63***	1.87
Outlet	12.39 (1.04)	10.35 (0.93)	119.71	20.39***	2.10
Sagittal diameters					
Inlet	12.46 (1.03)	11.92 (1.02)	104.53	5.17***	0.06
Midplane 1	13.15 (0.99)	12.78 (0.90)	102.90	3.90***	1.37
Midplane 2	12.28 (0.87)	11.65 (0.75)	105.41	7.54***	4.16*
Outlet	9.99 (0.98)	9.60 (0.74)	104.06	4.53***	17.22***
Conjugata diagonalis	13.70 (0.98)	13.50 (1.04)	101.48	1.93	1.21
Additional sagittal diameter S2-S3	13.76 (0.98)	13.47 (0.90)	102.15	3.08**	0.91

Table 3.1 (continued)

Parameters	Females (n=211)	Males (n=181)	Coefficient of dimorphism	Stjudent's *t* test	Levene's test
	M (SD)	M (SD)			
Pelvic angles					
Sacral slope	39 (7)	39 (6)	100.00	-0.13	1.11
SAO	58 (10)	56 (9)	103.57	2.38*	2.24
Pelvic inclination	64 (7)	62 (6)	103.23	3.66***	1.97
Angulus subpubicus	132 (12)	94 (12)	140.43	31.17***	0.95
Additional diameters					
Distantia intercristalis	28.21 (1.70)	28.66 (1.59)	98.43	-2.68**	0.42
Distantia interspinosa	23.88 (1.94)	24.28 (1.70)	98.35	-2.16*	2.34
Distantia intertrochanterica	30.10 (1.44)	31.47 (1.68)	95.65	-8.68***	1.71
Transverse diameter of the thorax	26.94 (2.11)	30.30 (2.14)	88.91	-15.30***	0.33
Pelvic indexes					
Index of inlet	0.93 (0.10)	0.94 (0.08)	98.94	-1.63	3.45
Index of Midplane 1	1.08 (0.10)	1.13 (0.10)	95.58	-4.44***	0.11
Index of Midplane 2	1.10 (0.10)	1.25 (0.14)	88.00	-12.37***	11.80**
Index of outlet	0.81 (0.11)	0.94 (0.11)	86.17	-10.93***	0.07

*p<.05, ** p<.01, *** p<.001

The comparison of means demonstrates that transverse diameters of the lesser pelvis are greater in females than in males. The most pronounced differences are observed in a distance between two ischial spines and in a distance between ischial tuberosities (Picture 3.1). The less pronounced dimorphism was observed in the transverse diameter of the inlet.

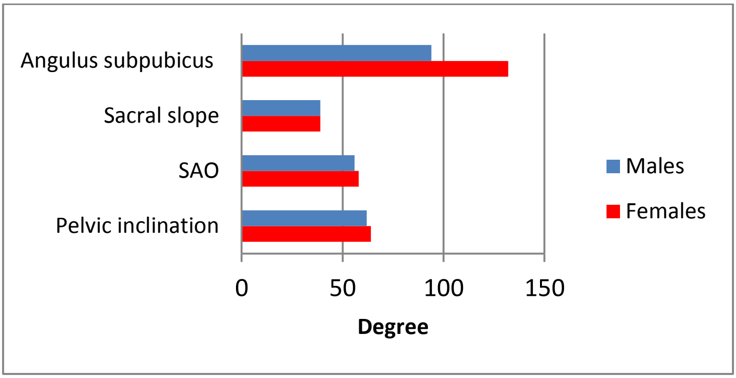


Picture 3.1 Sexual dimorphism of linear measures of the lesser pelvis

Sagittal diameters of the lesser pelvis are also greater in females than in males. The most pronounced differences are observed at a level of the ischial spines. At the same time, there were no significant differences between sexes in diagonal conjugate (*conjugata diagonalis*).

Coefficients of dimorphism vary from 106.47 for the transverse diameter of the inlet to 119.87 for the transverse diameter of Midplane 2. Coefficients of dimorphism for sagittal diameters are lower than those for transverse diameters. For sagittal diameters with significant differences, these coefficients vary from 102.15 for the additional sagittal diameter S2-S3 to 105.41 for the sagittal diameter at the level of ischial spines.

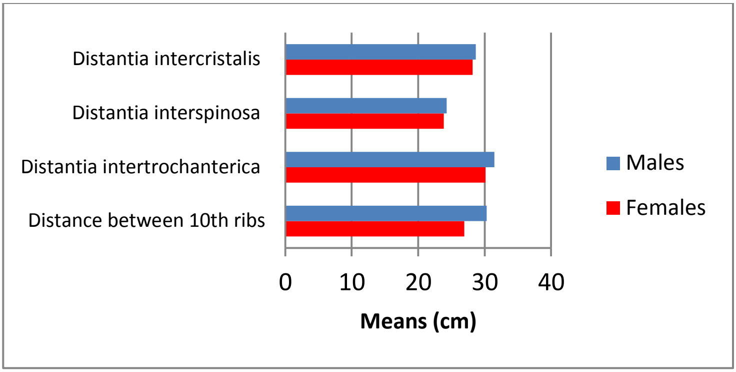
Three of four angles are significantly higher in females than in males (Picture 3.2). The most pronounced dimorphism is observed in subpubic angle (*angulus subpubicus*). However, there were no significant differences in sacral slope between males and females.



Picture 3.2 Sexual dimorphism of pelvic angles

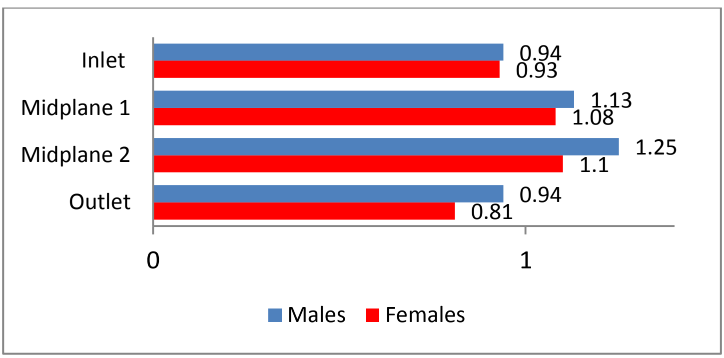
The *angulus subpubicus* has the highest coefficient of sexual dimorphism (140.43), it is followed by sexual dimorphism in SAO (103.57), and in pelvic inclination angle (103.23). Sacral slope has a coefficient of sexual dimorphism equal to 100 that reveals no significant differences for means of this angle in females and in males.

In contrast, males have greater additional parameters representing body width than females (Picture 3.3). For the false pelvis, the most pronounced difference is observed in the distance between greater trochanters (*distantia intertrochanterica*) when the lowest difference is observed in the distance between two iliac crests (*distantia intercristalis*). For all additional measures, coefficients of sexual dimorphism vary from 88.91 in the transverse diameter of the thorax to 98.43 for *distantia intercristalis*.



Picture 3.3 Sexual dimorphism of body width

Performed comparison of pelvic indexes indicates that an index of the pelvic inlet is similar for females and males (Picture 3.4). Indexes of proportions at the level of acetabular centers (the Midplane 1), at the level of ischial spines (Midplane 2), and the outlet differ significantly for two sexes.

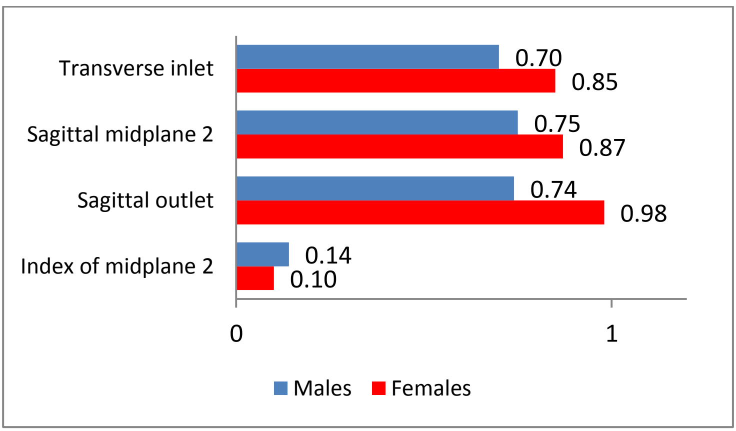


Picture 3.4 Sexual dimorphism of pelvic indexes

In the middle of the pelvic cavity, indexes are greater than 1.00. It means that the middle part of the cavity has slight sagittal-oval shape. The outlet is more transversely flattened in females than in males. The differences between sagittal and transverse diameters in females are lower than in males. It indicates more cylindrical shape of the pelvic cavity in females.

The most pronounced sexual dimorphism was observed in the shape of the outlet and the cavity at the level of ischial spines. Coefficients of sexual dimorphism of four pelvic planes vary from 86.17 for the outlet plane to 98.94 for the inlet plane.

Levene's test of equality of variance revealed significant differences in four pelvic dimensions (Picture 3.5). Variance of the transverse diameter of the inlet, of the sagittal diameter at the level of ischial spines, and of the sagittal diameter of the outlet is greater in females than in males. At the same time, the index of proportion at the level of ischial spines has greater variance in males than in females. For this midcavity plane, a sagittal diameter and a transverse diameter are closely interrelated in females.



Picture 3.5 Differences of variances of pelvic measures

For other lesser pelvis measures, variances are equal. The same tendency was observed in additional measures.

3.2 The relationship between measures of the narrowest pelvic place and other pelvic measures

The correlation analysis shows that in females the diameters at level of ischial spines are closer connected to other pelvic parameters. The transverse diameter of Midplane 2 correlates with the rest of cavity parameters in females in the interval from .60 to .72, but in males from .44 to .60. The comparison of this correlation with Fischer z test proved that all three correlations in females are significantly higher (z values from 2.05 to 2.16, $p<.05$).

Sagittal parameter at level of ischial spines in females also correlates with the rest of parameters much closer than in males. Fischer z test confirms, that the correlation of this sagittal parameter with the distance between greater trochanters (*distantia intertrochanterica*) in females is significantly higher than in males ($z=2.18$, $p<.05$).

To answer the question about the predictors of narrowest diameters of the lesser pelvis, a multiple step linear regression was performed with pelvic parameters at the level of ischial spines (transverse diameter and sagittal diameter of Midplane 2) as independent variables and greater pelvis and lesser pelvis measures as the dependent variables. The first step included measures of the greater pelvis as independent variables. Transverse diameters of the lesser pelvis were added at the second step, but sagittal diameters of the lesser pelvis were added at the third step. Taking into account the pronounced sexual dimorphism, the regressions were calculated separately in female and male samples.

The results of a multiple step linear regression analysis in the female group show that the only of the greater pelvis measures, which allows to explain the transverse diameter of Midplane 2 is the distance between greater trochanters (*distantia intertrochanterica*). However, by adding this model by the lesser pelvis diameters, *distantia intertrochanterica* contribution significantly decreases. The greatest increase in the determination coefficient is related to the inclusion of the lesser pelvis transverse diameters into the model (ΔR^2=.40). This increase in explained variance is caused by adding the transverse diameter of the inlet and the transverse diameter of the outlet. In the third step, the determination coefficient is still slightly increasing, which is due to a slight contribution of the sagittal diameter of the outlet in explaining of variance of the diameter between ischial spines. In total, four pelvic diameters explain 69% of variance of transverse diameter of Midplane 2. It is closer connected to the transverse diameters of the outlet and the inlet, which are followed by *distantia intertrochanterica* and the sagittal diameter of the outlet.

The next regression model shows that the contribution of greater pelvis measures in the prediction of the sagittal diameter of Midplane 2 differs from its contribution in transverse diameter prognosis. If at the first and the second regression step *distantia intertrochanterica* explains some part of variance of the sagittal diameter of Midplane 2, then at the third regression step neither of the larger pelvis measures explains variance of this diameter. The greatest increase in the coefficient of determination is related to the inclusion of the lesser pelvis sagittal sizes into the model (ΔR^2=.40). In total, 58% of variance of the sagittal diameter of Midplane 2 in females is explained by the sagittal diameter at the level of acetabular centers and the sagittal diameter of the outlet. It should be noted, that both diameters – sagittal and transverse – at the level of ischial spines in the female sample are not related to the diagonal conjugate (*conjugata diagonalis*).

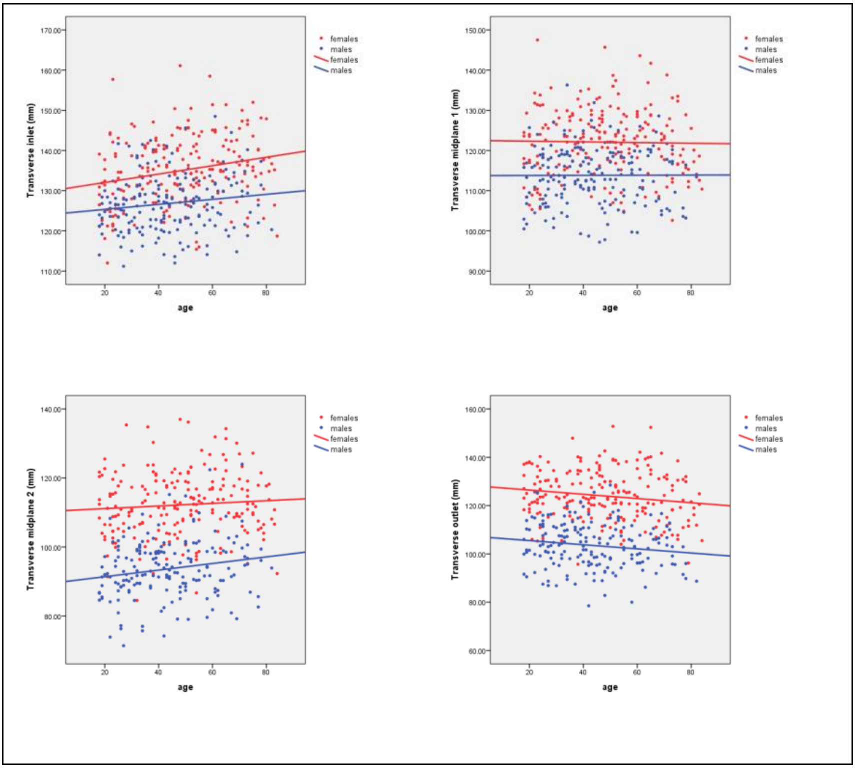
The results of a regression analysis in the male sample demonstrate that *distantia intertrochanterica* does not explain variation of the transverse diameter of Midplane 2, when lesser pelvic sizes are added to the model. At the third step, the determination coefficient indicates that the transverse diameter of the inlet and the transverse diameter of the outlet explain 51% of variance of the transverse diameter of Midplane 2. It is possible to conclude that this diameter is less related to other diameters of the lesser pelvis in the male sample than in the female sample. Neither of the greater pelvis measures or the lesser pelvis sagittal diameters explains variance of the distance between ischial spines in males, if simultaneously transverse diameters of the lesser pelvis are analyzed.

Variance of the sagittal diameter of Midplane 2 in the male sample is explained by two sagittal diameters of the lesser pelvis. The sagittal diameter of the outlet and the sagittal diameter at the level of acetabular centers explain 45% of variance. This regression model also confirms lower interrelations among pelvic parameters in males than in females.

3.3. Age-related changes of pelvic parameters

Age-related changes of pelvic parameters were analyzed taking into account sexual dimorphism of these parameters. Therefore, age, sex, and their interaction were independent variables while each of pelvic measures was a dependent variable for a particular linear regression model.

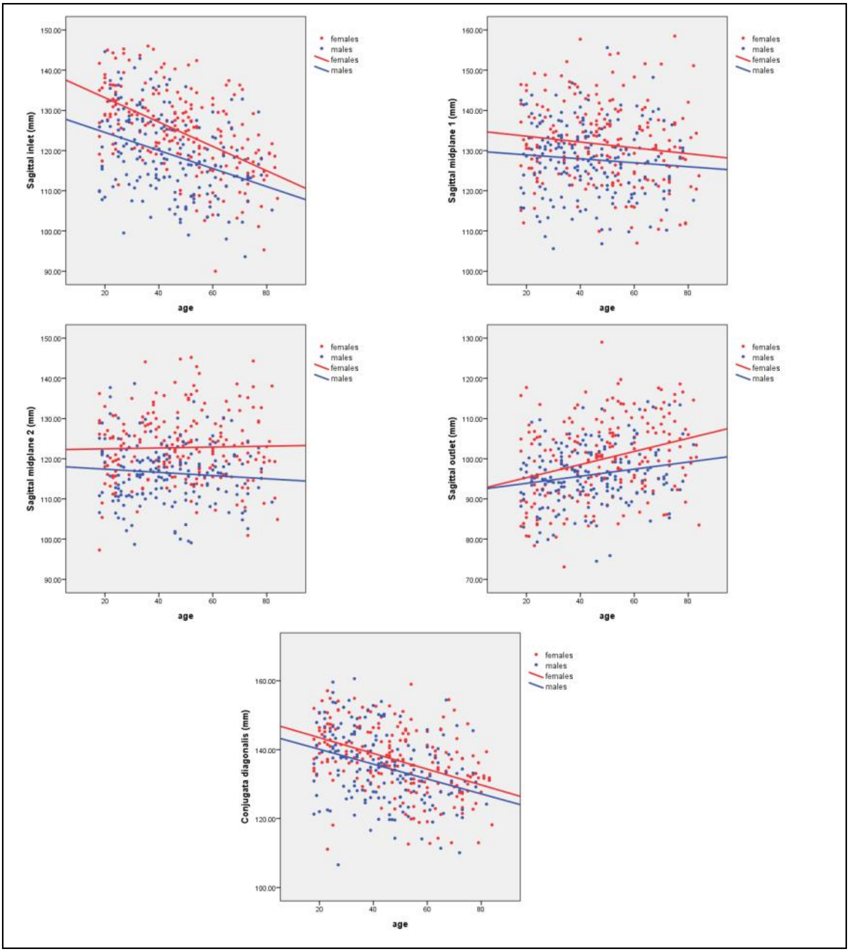
Three of four transverse lesser pelvic measure are age-dependent that is represented by regression lines (Picture 3.6). The transverse diameter of the inlet increases with age. Less significant increase is observed in the transverse diameter of Midplane 2. The distance between two acetabular centers is not dependent on age. In turn, the transverse diameter of the outlet decreases with age. There was no significant age-sex interaction, and tendencies of change are similar for females and males.



Picture 3.6 Age-related changes of the transverse diameters of the lesser pelvis

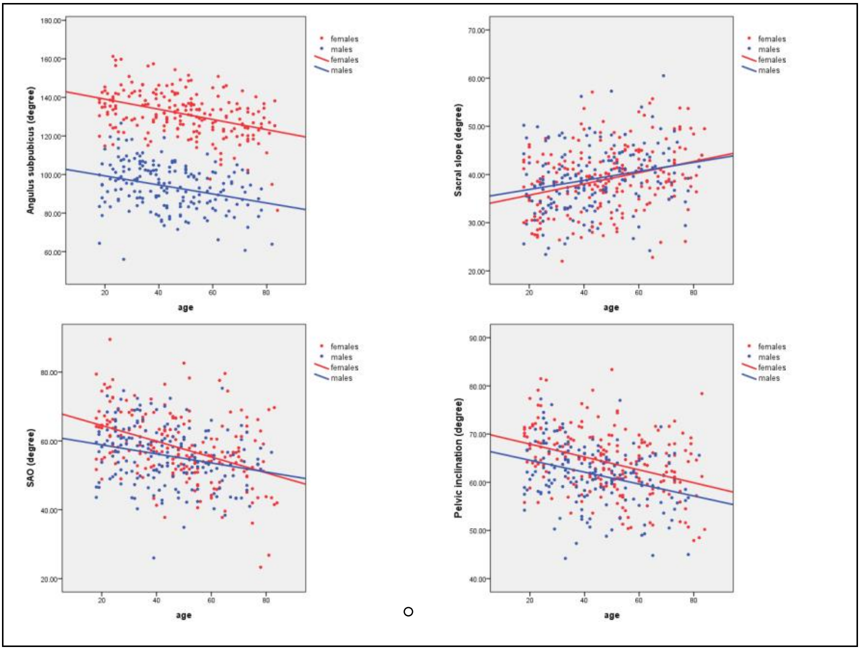
Four of five sagittal dimensions of the lesser pelvis are significantly age-dependent. However, sagittal Midplane 2 is not related to age (Picture 3.7).

The sagittal diameter of the inlet decreases with age. High slope of the regression line confirms that changes are occurring relatively rapidly in females and in males. The sagittal diameter of Midplane 1 also decreases with age. However, observed change of this diameter is not rapid. The sagittal diameter of Midplane 2 is not related to age. The sagittal diameter of the outlet increases with age. Observed tendencies are common for the female and male samples. In addition, the diagonal conjugate (*conjugata diagonalis*) decreases with age. This parameter is changing without sexual dimorphism in the sense of means.



Picture 3.7 Age-related changes of the sagittal diameters of the lesser pelvis

The results of a regression analysis demonstrate that all pelvic angles are age-dependent. Tendencies of change are similar for both sexes because there is no significant age-sex interaction (Picture 3.8).

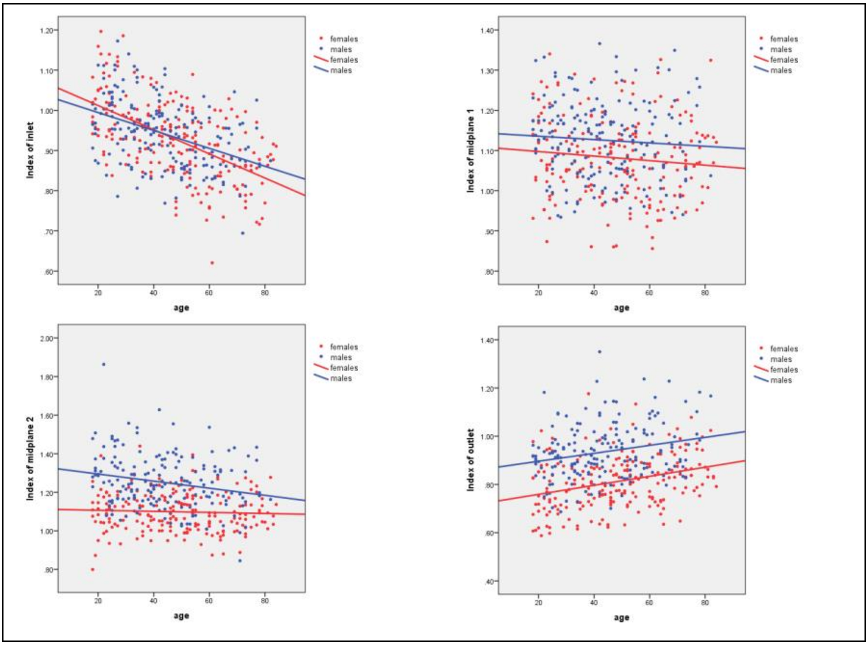


Picture 3.8 Age-related changes of pelvic angles

The subpubic angle (*angulus subpubicus*) decreases with age. Similar changes in males and females are visible as similar slopes of regression lines. The distance between these lines reflects the most pronounced sexual dimorphism of this parameter. Sacral slope increases with age. This parameter demonstrates non-significant sexual dimorphism. Sacral anatomical orientation angle (SAO) is decreasing with age. Pelvic inclination angle is also decreasing. For both sexes, changes are concordant with a moderate level of sexual dimorphism for observed means.

A regression analysis on pelvic indexes indicates a significant decrease at the inlet plane and an increase at the outlet plane (Picture 3.9). An index of Midplane 1 (at the level of acetabular centers) is not age-dependent. Midplane 2 (at the level of ischial spines) has an index decreasing with age.

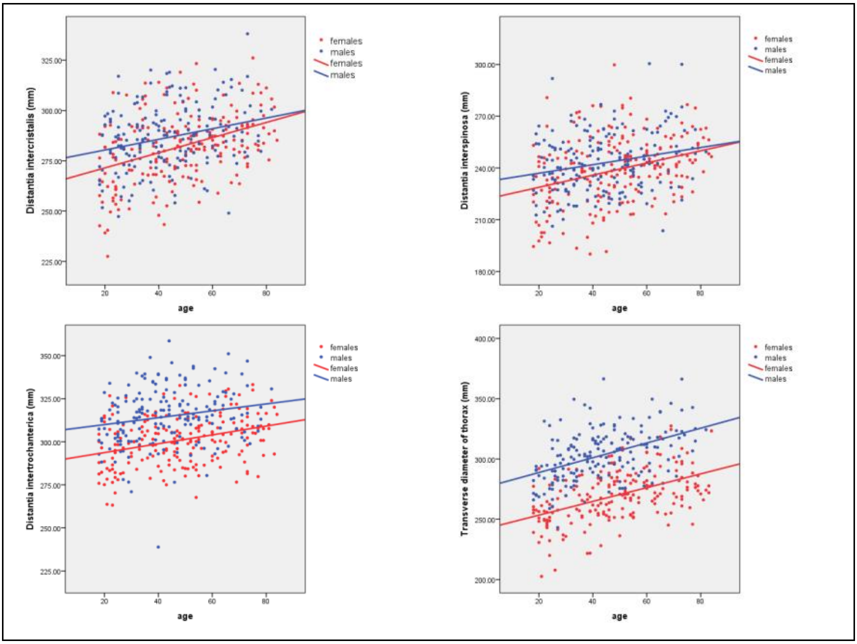
The results also confirm sexual dimorphism in the outlet, Midplane 1, and Midplane 2, and no sexual dimorphism in the pelvic inlet.



Picture 3.9 Age-related changes of pelvic indexes

If indexes of the inlet, outlet, and Midplane 1 are changing similarly in males and females, an index of the Midplane 2 demonstrates a significant age-sex interaction. An additional analysis was performed in order to assess this interaction. The results demonstrate significant age-related decrease in the male sample, $F(1,180)=8.37$, $p<.01$, and no decrease in the female sample, $F(1,210)=0.50$, $p=.48$. Therefore, this index is changing with age in males only.

A regression analysis demonstrates increase in additional measures: *distantia intercristalis*, *distantia interspinosa*, *distantia intertrochanterica,* and the distance between 10^{th} ribs (Picture 3.10). Significant sexual dimorphism confirms that these measures are greater in males than in females. Age-related changes of additional parameters are also concordant for both sexes. There is no significant age-sex interaction and observed slopes of regression lines are similar.



Picture 3.10 Age-related changes of transverse measures of body

The results do not confirm the hypothesis suggesting sex-related differences in age-related changes of the lesser pelvis. The index of proportion at the level of ischial spines is only one parameter demonstrating significant differences of age-related tendencies for females and males. It is one of 21 regression models that is less that 5% of cases, and this percent is no greater than a statistical error.

4. DISCUSSION

The results of the study demonstrate a pronounced sexual dimorphism in means of pelvic measures and in the level of interrelations of these parameters. The analysis of the interrelations of pelvic parameters reveals that the narrowest pelvic diameters are closer connected with the measures of the lesser pelvis and are significantly less dependent on the transverse measures of the greater pelvis. The hypothesis about the variance of the lesser pelvic parameter in the plane at the level of ischial spines was confirmed, while the hypothesis about the different tendencies of age-related changes was not confirmed because the tendencies are similar in both genders.

4.1. Manifestations of the pelvic sexual dimorphism

All diameters in the frontal plane (transverse diameters) demonstrate sexual dimorphism. In addition, the coefficients of dimorphism of transverse measures are higher than those of sagittal measure. The highest coefficients of dimorphism were found to be in transverse diameters at level of ischial spines and at level of pelvic outlet, while the lowest coefficients were observed in the inlet plane and in the distance between acetabular centers. It proves about more marked female pelvic changes in the transverse direction rather than in the antero-posterior direction and in the lower parts than in the upper parts of the pelvis during the evolution.

Sagittal diameters also demonstrate sexual dimorphism, except for the diagonal conjugate (*conjugata diagonalis*) length. The most pronounced sexual dimorphism is found in the sagittal diameter located in Midplane 2 (at the level of ischial spines). The slightest sexual differences were found in sagittal diameter at the level of acetabular centers and in an additional sagittal diameter S2-S3. A similar tendency in sexual differences was found in *Tague*, *Coleman* and *Correia et al*. studies (*Coleman,* 1969; *Tague*, 1989; *Correia et al*., 2005). In accordance with other studies, the current study confirms that the narrowest diameter for both sexes is the distance between ischial spines, and the widest diameter is the transverse diameter of the inlet (*Tague,* 1992; *Walrath and Glanz*, 1996; *Correia et al*., 2005; *Kurki*, 2007; 2011; *Salerno et al*., 2006).

The index of the inlet shows that the inlet shape is similar in males and females: slightly transverse oval, because the transverse diameter of the inlet is slightly bigger than its sagittal diameter. An absence of sexual dimorphism in the pelvic inlet was found in other studies as well (*Young and Ince,* 1940, *Holland et al*., 1982; *Tague*, 1992).

Proportions of the pelvic cavity at levels of acetabular centers and of ischial spines differ significantly in females and males. In females the pelvic cavity at these levels is slightly stretched in sagittal direction. Besides, the pelvic cavity at the level of acetabular centers is more round than at the level of ischial spines. In males, it is possible to observe similar tendencies in the cavity shape at both levels, but the elongation in sagittal direction is bigger than in females.

At the outlet level, the pelvic cavity for both sexes is stretched in transverse direction, which is related to the ventral placement of the coccyx. This description of the outlet shape does not correspond to its traditional description in obstetrics, when the outlet is characterized as sagittaly stretched, similarly to shape of the level of ischial spines (*Thoms and Wilson,* 1939; *Schultz,* 1949). These differences in the description of the outlet shape are caused by differences in detection of level of the outlet. In obstetrics (*Thoms and Wilson,* 1939; *Stalberg et al*., 2006; *Lenhard et al*., 2010) as well as in paleoanthropological studies (*Tague,* 1989; *Correia et al*., 2005) the outlet includes the tip of the sacrum that is higher than the level of the outlet in the doctoral thesis.

The sexual dimorphism of the pelvic indexes demonstrate that the most pronounced dimorphism belongs in the lower part of the pelvic cavity. In this part, the pelvic cavity in females is more cylindrical than in males. For the level of acetabular centers, a degree of sexual dimorphism is lower than for levels of ischial spines and of the outlet, while there are no sexual differences for the inlet. This finding is in accordance with the conclusions, acquired in the studies based on skeletal collections (*Tague*, 1989; 1992; *Correia*, 2005; *Kurki*, 2011).

In females, the subpubic angle is wider than in males. The pronounced sexual dimorphism of this parameter was found also in *Coleman* (1969) and *Tague* (1989; 1992). The results of the doctoral thesis do not confirm the sexual differences in sacral slope, similarly to *Mac-Thiong et al.* study (*Mac-Thiong et al.*, 2011) and opposite to *Amonoo-Kuofi* study results, which found a wider angle in females (*Amonoo-Kuofi*, 1992).

The pelvic inclination in females is higher that indicates a slightly more vertical placement of the inlet in females than in males. This confirms the result of the previous study (*Coleman*, 1969). The reason of it could be a weaker development of abdominal muscles and more frequent lumbar hyperlordosis in females than in males (*Damasceno et al*., 2006).

Sacral anatomical orientation angle (SAO) in females is wider than that in males. *Peleg et al*. mention that the angle does not possess any sexual differences and it does not differ between various ethnic groups as well (*Peleg et al*., 2007). But this study shows that in females the sacrum is located more horizontally than in males. Controversies in the results of both studies can be explained by SAO angle detection method. In *Peleg et al*. study the angle was determined in pelvic bones collection with the goniometer. In the current study, the angle was determined on the CT workstation in the live humans' group, following the angle definition described in *Peleg et al*. (2007). The difference between females and males in this parameter was about 2°. It can be determined only by a precise measurement method; here it is the computer tomography pelvimetry (*Anderson et al*., 2005).

Higher variance of the sagittal diameter of Midplane 2 and of the sagittal diameter of the outlet in females was found also in *Tague* work (*Tague*, 1989). The main explanation for higher variance of these diameters is related to increasing pelvic sizes during the labour, which is ensured by changes in pelvic joints under an influence of relaxine (*Tague*, 1989). An increase of the pelvic volume during the childbirth in a certain diameter is decreasing the intensity of adaptation of the pelvic cavity in this diameter. In addition to *Tague* study (1989), higher variance in females than in males is detected also in the transverse diameter of the inlet. As it has been demonstrated earlier (*Weisl*, 1955; *Russel*, 1969), this diameter also is increasing during the labour. Higher variance in some parameters of the pelvic cavity provides an evidence for a higher plasticity of the female pelvis, which is necessary in order to provide an effective reproductive function.

Lower variance in females than in males is found in the index of proportions at the level of ischial spines. This finding confirms the first hypothesis. Taking into account that correlation of diameters of the pelvic cavity at level of ischial spines is higher in females than in males, they are changing in a coordinated way. For the female pelvis, it provides more rounded shape of the cavity at this level and lower variance of the proportion of the plane.

4.2 The relationship between measures of the narrowest pelvic place and other measures

In general, the current study demonstrates higher correlation coefficients between the pelvic measures than other studies do (*Young and Ince*, 1940; *Ridgeway et al*., 2011), which might be caused by differences in a method of pelvimetry. *Ridgeway et al*. study was performed on skeletal collections (*Ridgeway et al*., 2011), *Young and Ince* study used the X-ray pelvimetry method (*Young and Ince*, 1940). In addition, the present study revealed higher correlations of pelvic measures in females than in males.

The results of regression analysis show that the distance between two ischial spines in females depends on four dimensions: the transverse diameters of the inlet and the outlet, the distance between greater trochanters (*distantia intertrochanterica*), and the sagittal diameter of the outlet. In males, this distance depends only on two dimensions: the transverse diameter of the inlet and the transverse diameter of the outlet.

Prediction of the pelvic cavity diameters at the level of ischial spines is a clinically important issue. On one hand, the clinical studies show that a risk for emergency cesarean section is associated with the sagittal diameter of the inlet (*Holland et al*., 1982; *Adadevoh et al*., 1989; *Abitbol*, 1991) and diameters of lower pelvic planes (*Zaretsky et al*., 2005; *Stalberg et al*., 2006; *Lenhard et al*., 2010). On the other hand, these studies demonstrate low sensitivity of antenatal pelvimetry in the prediction of labour outcome (*Ferguson et al*., 1998; *Abitbol*, 1991).

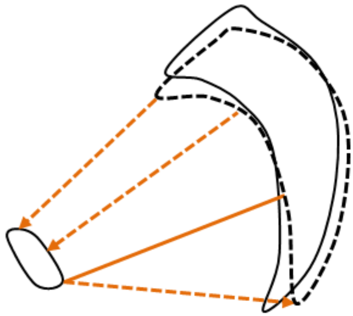
The dimensions of the greater pelvis and the diagonal cojugate (*conjugata diagonalis*), which can be determined by bimanual examination (*Crelin*, 1969), were also included in the regression analysis because attempts of predicting the labour outcome by these parameters. On the basis of a regression analysis, it is possible to conclude that the sagittal diameter of the inlet, *conjugata diagonalis*, the distance between iliac crests (*distantia intercristalis*), and the distance between anterior superior iliac spines (*distantia interspinosa*) are not sufficiently significant predictors of the pelvic cavity diameters at the level of ischial spines in females.

Topicality of predictions of the narrowest place of male pelvis is also connected with its clinical application. It has been reported that males with a narrower and deeper pelvic cavity have a longer operative time (*Hong et al*., 2007; *Rabbani et al*., 2009), as well a higher risk of blood loss (*von Bodman et al*., 2010) and other complications during pelvic organs surgery. Results of the doctoral thesis demonstrate that it is impossible to predict diameters of the narrowest plane in males by taking into account easily identified external pelvimetry indexes.

4.3.Age-related changes of pelvic parameters

Despite the observed sexual dimorphism of the pelvic structure, the results demonstrate common age-related changes in pelvic architecture in females and males. The only size which demonstrated different age-related trends in males and females was the index of proportions at the level of ischial spines. This index decreases faster in males.

Changes in sacral slope and SAO angle confirm more horizontal orientation of the sacrum with aging, which corresponds to the previous study results (*Amonoo-Kuofi*, 1992; *Peleg et al*., 2007). On one hand, it can be attributed to the changes in the sacroiliac joint and the decrease of their mobility with age (*Peleg et al*., 2007). On the other hand, the reason can be a shifting of the center of gravity of the body forward, which is observed in older people (*Schwab et al*., 2006). Detected changes in linear dimensions can confirm more horizontal orientation of the sacrum with age, because the two upper sagittal diameters decrease, but the sagittal diameter of the outlet increases with age (Picture 4.1), corresponding to the nutation mechanism (*Kapandji*, 2008).



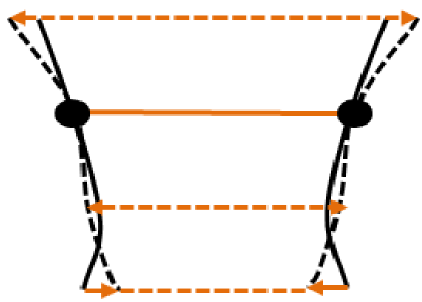
Picture 4.1 Age-related changes of pelvic measures in the sagittal plane

Broken black line shows a changing position of sacrum with age, but broken orange line shows the tendencies of changes in the sagittal plane.

Summarizing the mentioned above, we can assume, that the changes of the pelvic cavity shape in a sagittal plane occur under the influence of vertical posture, affecting the reduction of mobility in the sacroiliac joint. Taking into consideration the fact, that no age-related change was found in the sagittal diameter at level of ischial spines, we can assume that an axis of this gradual shift forward rests between the 4th and 5th sacral vertebras. It is lower than it was described by *Farabeuf* (*Kapandji*, 2008). It is possible that the placement of an axis of sacral rotation also changes with age.

In the frontal plane (Picture 4.2), the transverse diameter of the inlet and the distance between ischial spines increase with age, when the transverse diameter of the outlet decreases with age. The changes in these diameters are concordant in females and males, though the means of these diameters are different for two sexes. At the same time, the distance between centers of acetabulums does not depend on age.

The described changes of parameters in the frontal plane can be related to the changing position of the sacrum. As it is described in *Weisl* work, the transverse diameter of the inlet slightly increases in females and males, which occurs simultaneously with the anterior tilting of the base of the sacrum and with a shortening of the sagittal diameter of the inlet. At the same time, the ischial eversion contributes to divergence of both ischial spines (*Weisl*, 1955). The discovered changes in transverse diameters of the inlet and the plane including ischial spines in females and males correspond to *Weisl* (1955) theory, which allows assuming of the age-related changes in these parameters under the influence of vertical posture.



Picture 4.2 Age-related changes of pelvic measures in the frontal plane

Broken black line shows changes of the pelvic cavity shape with age in the frontal plane, but the broken orange line shows the tendencies of changes in the transverse measures.

An opposite tendency was found in the transverse diameter of the outlet. In older people, the distance between ischial tuberosities (the transverse diameter of the outlet) is shorter than in younger people. The changes in this parameter theoretically can be related to adaptation of the pelvic bone system for a sitting position because the load in this position increases on ischial tuberosities (*Pauwels*, 1948; *Moes*, 2007), which can promote a decrease in the transverse diameter of the outlet with age.

The transverse diameter between two acetabular centers takes a special place in the analysis of the frontal plane measures. Regression analysis confirms the independence of this distance from age and its dependence on gender, because in females the pelvic cavity at this level is wider than in males. It means that the distance between pelvic rotation centers in the frontal plane (the centers of the hip joint) remains unchanged despite described age-related changes of the pelvic cavity at other levels.

The previous works show significance of the superior midplane in bipedal locomotion (*Lovejoy*, 1988; 2002). Firstly, the body weight is evenly distributed on two extremities through the acetabular centers (*Pauwels*, 1948). Secondly, flexion and extension of the torso occur around the axis, which passes between both hip joints (*Kapandji*, 2008). Therefore, the cavity width at this level was affected by the necessity to adapt to a vertical posture in order to ensure a better balance and effective movement based only on two extremities (*Lovejoy*, 1988). It means that the distance between centers of hip joints remains unchangeable in order to provide more effective locomotion in both females and males.

Taking into account observed changes of linear measures in the analysis of changing indexes, it is possible to conclude that the pelvic cavity in females and males slightly flattens in the transverse direction at the inlet level and at the level of ischial spines, while it lengthens in the sagittal direction at the level of the outlet. The shape of the pelvic cavity at level of acetabular centers does not change with age. In females and males, the shape of the inlet and outlet changes in a concordant way, but the shape of the cavity at level of ischial spines changes only in males.

Unchanging cavity proportions at the level of ischial spines in females can be explained by more intensive adaptation occurred during the human evolution, which affected the female pelvic cavity at the level of its narrowest plane (*Abitbol*, 1987; *Tague*, 1989; 1992). It is possible that this additional adaptation of the female pelvis resulted in a higher genetic determination of this cavity parameter, which preserve the proportion of the narrowest place in the pelvic cavity as independent of age.

Sexual differences in the aging rate were identified in morphology of some skeletal bones: density of long bone (*Lauretani et al*., 2008), and morphology of lumbar vertebrae and of iliac crest (*Ostjic et al*., 2006). Results of the doctoral thesis cannot reveal structural changes of pelvic bones, but the changes of the diameters of pelvic cavity demonstrate similar change rate in females and males at all levels, except for the level of ischial spines, in which a ratio of the diameters is not changing with age in females.

Measures of the greater pelvis and the transverse diameter of thorax increase with age. This tendency corresponds to the results of an earlier study (*Gillette-Guyonnet et al*., 2003). The main reason for the increase of the width of thorax in older age is the decreasing of skeletal muscle tonus (*Launer et al*., 1996), while the sizes of the greater pelvis increase, because the abdominal muscle tonus decreases.

The aging tendencies of the lesser pelvis parameters show that, despite the different growth trajectories of the pelvic cavity parameters in the age from 8 to 18 years (*Coleman*, 1969; *LaVelle*, 1995), further aging in the pelvic cavity does not demonstrate sexual dimorphism in changes, which is contrary to the research hypothesis. Common changes of pelvic measures in females and males can be related to genetic similarity of homological structures (*Tague*, 2000), which is expressed during the aging of the pelvic bone system.

Analysis of age-related changes of the pelvis opens an opportunity to interpret the results in the context of a risk of the development of pelvic floor diseases, which extends a practical significance of the study. There is evidence that the risk of development of pelvic organ prolapse, urinary and fecal incontinences increases with age (*MacLennan et al*., 2000; *Stav et al*., 2007). Despite sexual differences in the pelvic floor structure, age is a pathology contributing factor in males (*MacLennan et al*., 2000). The main explanation in the development of these pathologies is related to the changes in the soft tissues of the inferior wall of the pelvic cavity (*Mallett et al*., 1994; *De Lancey et al*., 2003). However, there are data that some characteristics of the bony pelvic shape can contribute to the development of the pelvic floor diseases (*Sze et al*., 1999; *Nguyen et al*., 2000; *Handa et al*., 2003; *Lazarevski*, 2004; *Xu et al*., 2011). The pelvic floor dysfunction and the pelvic organ prolapse are observed more often in females with a wider and shorter pelvic inlet (*Sze et al*., 1999; *Nguyen et al*., 2000; *Handa et al*., 2003), a more horizontally oriented pelvic inlet (*Lazarevski*, 2004), a wider distance between ischial spines (*Xu et al*., 2011) and a longer sagittal diameter of the outlet (*Lazarevski*, 2004). But it is not clear whether the changes of the pelvic bone system can be an independent factor in the development of the above-mentioned pathologies.

4.4. Limitations of the study and further directions

A generalization of the findings to the adult population in Latvia is limited by selected research participants – patients of one hospital which had undergone computer tomography examination according to clinical indications. However, an attempt to obtain an extended and more representative sample will be related to the problem of ionizing radiation for people without indications for examination.

Quotas of subjects by sex ar close to the population proportions, but the exclusion of study subjects due to numerical variations of lumbar vertebrae was uneven. As a result, in some age groups after ten year intervals, the population proportions have not been precisely followed. Therefore, the tendencies of the sexual dimorphism and the aging were analyzed in full groups of females and males without dividing them into smaller age groups. In order to reveal the tendencies at each age interval, further studies are needed.

Another limitation of the study relates to a cross-sectional design attempting to reveal tendencies of age-related changes in live humans. It should be considered as a certain shortcoming of anthropological studies (*Mac-Thiong et al.*, 2011). However, in this case, the inclusion of individuals in the longitudinal study is related to repeated radiation doses because of following individual changes during the lifetime.

Regulations for personal data protection limited the clinical applicability of the study. There was a lack of information on the number and outcome of childbirth, the possible pelvic floor diseases or pains in the lumbar and sacral regions, which not allow to assess the characteristics of the pelvic cavity in relation to these clinically important issues. The general anthropometric parameters were also not identified in the study, because primarily the study was aimed at the obtaining of new anthropological data, using radiological archives of materials based on modern diagnostic technologies.

Further studies can deal with the investigation of the pelvic architecture and the development of various pathologies in the pelvic cavity. One of the study directions could be the relation of the pelvic cavity shape with the pelvic floor disorders in males. Another point of interest is the relation of age-related changes in the pelvic architecture and pain of unknown etiology in the pelvic cavity.

5. CONCLUSIONS

1. Sexual dimorphism of the lesser pelvis manifests itself unevenly in different pelvic levels. The most pronounced sexual differences have been found in the pelvic cavity at the level of ischial spines. Simultaneously with differences in means of linear measures, lower variance of the index of proportions at this level was observed in females than in males. This finding provides an additional evidence for more intensive evolutionary change of the female pelvis.
2. Higher variance in females than in males is found in the transverse diameter of the inlet, in the sagittal diameter at the level of ischial spines, and in the sagittal diameter of the outlet. It supports a greater plasticity of the female pelvic cavity.
3. The measures of the pelvic cavity at the level of ischial spines are interrelated closer in females than in males. Measures of the narrowest place of the pelvic cavity demonstrate a closer relationship with the transverse diameters of the inlet and outlet, the sagittal diameter at the level of acetabular centers, the sagittal diameter of the outlet, and the distance between the greater trochanters.
4. For both sexes, the sagittal diameter and the transverse diameter at the level of ischial spines are not sufficiently closely dependent on the sagittal diameter of the inlet, the diagonal cojugate, the distance between iliac crests, and the distance between anterior superior iliac spines. Therefore, these parameters are not significant predictors for the narrowest place of the pelvic cavity.
5. In females and males, there are observed common aging trends in the pelvic architecture. The most part of the lesser pelvic measures is dependent on age, except for the distance between acetabular centers and the sagittal diameter at level of ischial spines. In females, the

index of proportions at the level of ischial spines also does not change with age, which is a new evidence of the sexual dimorphism. The age-related deformations of the pelvic cavity are more expressed at levels of the inlet and of the outlet and less in the middle part of the cavity, preserving the placement of the pelvic rotation centers in the frontal plane at the level of acetabular centers.

SCIENTIFIC PUBLICATIONS AND PRESENTATIONS ON RESEARCH THEME

Publications:

1. Koļesova O., Vētra J. Iegurņa pamatizmēru savstarpējo sakarību dzimumatšķirības. RSU zinātnisko rakstu krājums, 2010; 430–436.
2. Kolesova O., Vetra J. Sexual dimorphism of pelvic morphology variation in live humans. Papers on Anthropology XX, 2011; 209–217.
3. Kolesova O., Vetra J. Female pelvic types and age differences in their distribution. Papers on Anthropology. Papers on Anthropology XXI, 2012; 147–154.
4. Kolesova O., Vētra J. Predictors of the narrowest pelvic cavity diameter in live females and males. Papers on Anthropology XXII, 2013; 96–103.

Congress abstacts:

1. Koļesova O., Vētra J. Iegurņa pamatizmēru dzimumatšķirības. RSU scientific conference, 2010, abstract, 43 pp.
2. Koļesova O., Vētra J. Mazā iegurņa proporciju atšķirības divās vecumgrupās. RSU scientific conference, 2011, abstract, 52 pp.
3. Kolesova O., Vetra J. Sexual dimorphism of pelvic morphology variation in live humans. Baltic morphology VI, Tartu, 2011, abstract, 69 pp.
4. Koļesova O., Vētra J. Iegurņu tipi Latvijas sieviešu izlasē, RSU scientific conference, 2012, abstract, 60 pp.
5. Koļesova O. Vētra J. Mazā iegurņa parametru vecuma izmaiņas, RSU scientific conference, 2013, abstract, 64 pp.

6. Koļesova O. Vīriešu iegurņa dobuma tipi divās vecumgrupās, 7th Congress of Latvian Doctors, 2013, abstract, http://www.arstukongress.lv/?&s=1361881321&fu=read&id=74
7. Koļesova O., Vētra J. Age-related Trends in Lesser Pelvis. Baltic morphology VII, Rīga, 2013, abstract, 69 pp.

Presentations:

1. 18.03.2010., poster, O. Koļesova, J. Vētra, „Iegurņa pamatizmēru dzimumatšķirības", RSU 9th scientific conference, Rīga.
2. 14.04.2011., poster, O. Koļesova, J. Vētra, „Mazā iegurņa proporciju atšķirības divās vecumgrupās", RSU 10th scientific conference, Rīga.
3. 22.09.2011., poster, O. Kolesova, J. Vetra, „Sexual dimorphism of pelvic morphology variation in live humans", Baltic morphology VI, Tartu.
4. 29.03.2012., poster, O. Koļesova, J. Vetra, „Iegurņu tipi Latvijas sieviešu izlasē", RSU 11th scientific conference, Rīga.
5. 20.04.2012., oral report, O. Koļesova, „Human bony pelvis. Pelvis as as research subject." Presentation of the main findigs at a seminar in the University of Lubljana, Slovenia, ERASMUS visit.
6. 21.03.2013., poster, O. Koļesova, J. Vētra, „Mazā iegurņa parametru vecuma izmaiņas", RSU 12th scientific conference, Rīga.
7. 27.06.2013., oral report, O. Koļesova, „Cilvēka mazā iegurņa telpiskās arhitektūras dzimumatšķirības un vecuma izmaiņas". Presentation of the main results of the doctoral thesis. Meeting of the Association of Clinically-Integrated Morphology (KIMA), Rīga.
8. 20.09.2013., poster, O. Koļesova, „Vīriešu iegurņa dobuma tipi divās vecumgrupās", 7th Congress of Latvian Doctors, Rīga.
9. 08.11.2013., oral report, O. Koļesova, J. Vētra, „Age-related Trends in Lesser Pelvis", Baltic morphology VII, Rīga.

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