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Correlation analysis of greater sciatic notch dimensions and his index in gender prediction based on hip bone

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ABSTRACT
BACKGROUND/AIM: The greater sciatic notch is important because the gender of the hip bone can be determined on the basis of its appearance and dimensions. Important parameters that are taken into consideration when measuring greater sciatic notch dimensions are: the width and depth of the greater sciatic notch, the width of the upper part of greater sciatic notch. It is important to monitor the ratio of the width and depth of the notch, when assessing the appearance alone. The aim of the study was to determine correlations between the upper part of the greater sciatic notch with the values of it's width, as well as between depth and width of the upper part of the great sciatic notch.

MATERIALS AND METHODS: The study was conducted prospectively on 98 hip bone, of which 56 were single and 42 were within the pelvis. The gender and age of the bones were unknown. All bones belonged to adults in the Bosnian population. The research is based on the osteometric measurements of the width and depth of the greater sciatic notch and width of the upper part of greater sciatic notch, that was used for index calculations of the upper part of the greater sciatic notch.

CONCLUSION: We recommend the unique formula for index calculations of the upper part of the greater sciatic notch $I=K + (s \times \overline{AC})$.

KEY WORDS: Hip bone, pelvis, sexual dimorphism, osteometry

I. INTRODUCTION
Gender differentiation using bones, remains very important as we strive to do it on the best and simplest possible way in very short time. Different parts of the human skeleton carry different morphological characteristics that can serve to determine gender with a certain degree of certainty. The pelvis is the part of the human skeleton that meets best these purposes, due to the fact that pelvis has numerous details that can reveal sexual differences. The pelvis is one of the most massive parts of the sceleton that decompose slower than others, and as such can surve these purposes – which is proven in number of recent studies [1, 2, 3]. In the first half of the XX century it was proven that pelvis has the most important role in determining gender - based on skeleton, especially it's upper and lower openings, greater sciatic notch and subpubic angle [4]. Many authors suggest formulas obtained using discriminant functional analysis for gender determination using hip bone. However, the authors state that the formulas are more accurate if they are used to determine sex based on the hip bone of individuals from the same population. The aim of this study was to determine whether there really are population differences on the hip bones. The study was conducted on hip bones from three different populations measuring seven standard measures. The results of the study showed that there were, but no significant differences in the accuracy of pelvic sex determination between different populations [1]. Steyn et al. observed the pelvis as a whole, and separately the hip bone and the sacrum. The study showed that the accuracy of gender assessment was the highest when the hip bone was observed, 79.1 - 93.5%. Between individual bone elements, the diameter of acetabulum performed the greatest precision for gender determination, 83.9% average [5]. Pelvic-based sexual dimorphism in children was demonstrated by Shutowski, indicating that male specimens had a narrower and deeper sciatic notch compared to female specimens [6]. A significant number of papers that dealt with skeletal gender predictions considered both population and racial affiliation. Patriquin et al. reported that the length of ischium (86% accuracy) was the most characteristic parameter for white population, while the acetabulum diameter (84% accuracy) was characteristic for Afro-American population. [7]. The authors referred that female type of sciatic notch (width is larger and depth is smaller) had bigger prevalence in English population compared to Americans

of either European or African descent. These population differences are most likely due to various environmental influences (e.g., vitamin D deficiency) [8]. There are many methodological approaches were employed in pelvic gender dimorphisam verification, resulting in extensive literature. Some authors observed different diameters of the pelvis, using classical morphometry and deriving specific indices based upon the gender of examined material [9, 10, 11, 12, 13]. The nature has allowed the individual anatomical variation and departures from the set norms within each sex. In addition, these variations are affected by multiple etiological factors such as cultural, environmental and genetic elements [10]. The aim of our study was to examine the correlations of the index of the upper part of the greater sciatic notch with the values of its width, depth and width of the upper part of the greater sciatic notch, as well as developing regression equation for calcuting the index of the upper part of great sciatic notch. Study of Sandhya et al reported that the mean value of width of the greater sciatic notch in female was bigger, while the greater sciatic notch was deeper in male hip bone, as well as male hip bone had higher mean value of greater sciatic notch [14]. It was well known from the literature that sex determination based on pelvic bone is possible with 80% accuracy. Sciatic notch variation was greater in females than in males, while age did not show significance [15]. Dnyanesh analyzed sexual dimorphism on 100 hip bones, where the author measured and calculated seven parameters: maximum width, maximum depth, posterior segment, index I, index II, total angle and posterior angle. Results of this study showed that sexual dimorphism was expressed on all parameters, except maximum depth [16]. Gender differences in the human pelvis are conditioned by its adaptive functions. The irregular shape of the hip bone is caused by forces acting on its. This primarily refers to the upright position of the body and the transfer of the weight from superior part of the body to the legs, as well as the function of the birth canal in women. The function of transferring body weight to the legs affected the size and shape of the bone, while the function of the birth canal in women primarily affected the shape of the pelvis. In addition, sexual selection has made sexual dimorphism even more pronounced. Thus, the overall shape of the pelvis is conditioned by its function gender differences in the human pelvis are conditioned by its adaptive functions [17].

II. MATERIALS AND METHODS

The study was designed as a prospective osteometrical and it was conducted in osteological cabinets at Department of Anatomy, Faculty of Medicine, University of Sarajevo. Total of 56 individualhip bone (34 left and 22 right) and 21 pelvis sample were observed (total of 98 hip bone - 43 right and 55 left). The pelvis and hip bones originated from Bosnia and Herzegovina adult population of unknown age and gender. Three parameters were measured: the width and the depth of the greater sciatic notch and the width of the upper part of the greater sciatic notch. In our study, point B was marked on the basis of ischial spine, because the very tip of the mentioned spine was ruined on most specimens. This marking of the lower limit of the great sciatic notch has already been described in the literature by Genoves [18]. Point A is posterior inferior iliac spine. Some authors used piriform tubercule. We did not use it because it is very variable and often absent. According to Lazorthesu i Lhezu piriform tubercule is absent in 27% cases on right side and 24,4% cases on left side in female Point D is the deepest point of the great sciatic notch [19]. Point C is at the intersection of ($\overline{\mathbf{AB}}$) - width of the greater sciatic notch with ($\overline{\mathbf{CD}}$) - depth of the greater sciatic notch.

The index of the upper part of the great sciatic notch was calculated as the ratio of the width of the upper part of the great sciatic notch and the maximum depth of the great sciatic notch.

Figure 1 - Dimensions of the great sciatic notch (A- posterior inferior iliac spine; B – ischial spine; ($\overline{\mathbf{AB}}$) - width of the greater sciatic notch; ($\overline{\mathbf{CD}}$) - depth of the greater sciatic notch, ($\overline{\mathbf{AC}}$) - width of the upper part of the greater sciatic notche [Osteological colletion of the department of Anatomy].

$$\mathbf{I}=\frac{\overline{AC}}{\overline{CD}}[20]$$

This index shows the ratio of AC and CD, as how many times the AC is smaller than the CD.
All of the hip bones that where with the width of the upper part of the greater sciatic notch more that 0.70 times lower than the depth (index of the upper part of greater sciatic notch I <0.70), were characterized as reliably male hip bone. If the index of the upper part of the greater sciatic notch showed values above I> 0.70, the hip bones were characterized as reliably female bones [20].
Quantitative data were collected using an electronic digital calliper (ATD – 8657; 0 – 150 mm; Manufacturer ATD Tools, Inc. China) and all measurements were expressed in millimetres.

Statistical methods: The results are elaborated, documented and presented in absolute numbers, relative numbers, and statistical values using the statistical indicators. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to analyse the normality of distribution for continous variables. Since there was no statistically significant deviation from the normal distribution p> 0.05, the arithmetic mean, standard deviation and standard error were used to display the mean values, and the comparison between the two groups was performed using an independent t-test. Correlation tests Pearson were used for the relationship and direction of the relationship between the variable variables. The influence of individual continuous variables on others was examined by regression analysis of the regression line equation Y = K + b1 x X (where the correlation coefficient was above 0.9) Y-dependent variable; K-constant, b1-coefficient; X-independent variable.For statistical analysis the software package SPSS for Windows (version 19.0, SPSS Inc, Chicago, Illinois, USA) and Microsoft Excell (version 11. Microsoft Corporation, Redmond, WA, USA) were used.

III. RESULTS

Minimum and maximum values of width and depth of the greater sciatic notch and width and the index of the upper part of greater sciatic notch

The maximum and minimum values of parameter in total sample are shown in Table 1.

Table 1. Data obtained by measurment of hip bones (male, female, total sample)

		N	Mean	Std. Deviation	Minimum	Maximum
(I≤0 .70) M	Width of greater sciatic notch (mm)	58.00	53.93	5.95	42.00	64.00
(I>0,70+) F	Width of greater sciatic notch (mm)	40.00	60.65	6.78	48.00	76.00
Total	Width of greater sciatic notch (mm)	98.00	56.67	7.09	42.00	76.00
(I≤0 .70) M	Depth of greater sciatic notch (mm)	58.00	33.47	3.43	26.00	42.00
(I>0.70+) F	Depth of greater sciatic notch (mm)	40.00	33.55	3.31	26.00	40.00
Total	Depth of greater sciatic notch (mm)	98.00	33.50	3.37	26.00	42.00
(I≤0 .70) M	Width of the upper part of the greater sciatic notch (mm)	58.00	19.57	4.57	7.00	28.00

(I>0.70+) F	Width of the upper part of the greater sciatic notch (mm)	40.00	28.85	4.63	20.00	48.00
Total	Width of the upper part of the greater sciatic notch (mm)	98.00	23.36	6.48	7.00	48.00
(I≤0 .70) M	Index of the upper part of the greater sciatic notch	58.00	0.58	0.11	0.21	0.70
(I>0.70+) F	Index of the upper part of the greater sciatic notch	40.00	0.86	0.11	0.71	1.26
Total	Index of the upper part of the greater sciatic notch	98.00	0.69	0.18	0.21	1.26

The width of the greater sciatic notch in the total sample ranged from 42 mm to 76 mm (mean 56.67 mm) (Table 1). The t-test showed that there was a statistically significant difference in the arithmetic means of the male and female hip bones (p = 0.0001).

Table 2. Data obtained by measurement for the left and right hip bones

		N	Mean	Std. Deviation	Minimum	Maximum
Left	Width of greater sciatic notch (mm)	55.00	56.62	7.50	42.00	72.00
Right	Width of greater sciatic notch (mm)	43.00	56.74	6.62	44.00	76.00
Left	Depth of greater sciatic notch (mm)	55.00	33.18	3.27	26.00	41.00
Right	Depth of greater sciatic notch (mm)	43.00	33.91	3.48	26.00	42.00
Left	Width of the upper part of the greater sciatic notch (mm)	55.00	23.27	6.24	7.00	35.00
Right	Width of the upper part of the greater sciatic notch (mm)	43.00	23.47	6.84	10.00	48.00
Left	Index of the upper part of the greater sciatic notch	55.00	0.69	0.17	0.21	1.00
Right	Index of the upper part of the greater sciatic notch	43.00	0.69	0.19	0.29	1.26

Paried t – test showed that there was no statistically significant difference in the arithmetic means of the width of greater sciatic notch of the left and right hip bone (p = 0.9), as well as no statistically significant difference in the arithmetic means of the depth of greater sciatic notch (p = 0,3), width of the upper part of the greater sciatic notch (p = 0,9) and the index of the upper part of the greater sciatic notch (p = 0,1) between left and right hip bone.

Index distribution of the upper part of the greater sciatic notch
The average values of the index of the upper part of the greater sciatic notch were 0.69 ± 0.17, and 50% of these values were in the range of 0.59-0.83

Correlation between index of the upper part of the greater sciatic notch with the values of width and depth of the greater sciatic notch and width of the upper part of the greater sciatic notch

Table 3. Correlation of the index with the width of the upper part, depth and width of greater sciatic notch of the hip bone (male, female and total sample)

		Width of the upper part of the greater sciatic notch (mm)	Depth of the upper part of the greater sciatic notch (mm)	Width of the greater sciatic noth (mm)
Index of the upper part of the greater sciatic notch (male)	Pearson Correlation	0,901**	0,135	0,419*
	p	0,0005	0,312	0,001
	N	58	58	58
Index of the upper part of the greater sciatic notch (female)	Pearson Correlation	0,776	0,064	0,255
	p	0,0005	0,697	0,113
	N	40	40	40
Index of the upper part of the greater sciatic notch (total)	Pearson Correlation	0,928**	0,047	0,558*
	p	0,0005	0,648	0,0005
	N	98	98	98

**** strong correlation , * medium strong correlation**

The index of the upper part of the greater sciatic notch is correlated with the width of the upper part of the greater sciatic notch, in the male sex ($r = 0.901$ $p = 0.0005$). The correlation is strong and positive, the higher index of the greater sciatic notch corresponds to the higher widths of the upper part of the greater sciatic notch. There is also a correlation with the width of the greater sciatic notch, $r = 0.419$ $p = 0.001$. The correlation is medium strong and positive. There is no significant correlation with the depth of the gretaer sciatic notch. In females, there is also a strong and positive correlation with the width of the upper part of the greater sciatic notch, while with the other two variables there is no significant difference $p < 0.05$. In the overall sample, there is also a strong correlation with the width of the upper part of the greater sciatic notch, $r = 0.928$, and a slightly weaker correlation with the width of the greater sciatic notch, $r = 0.558$. While the correlation with the depth of the greater sciatic notch is not significant, $p < 0.05$.

In our study, this parameter presented a high correlation with the examined index ($r = 0.928$; $p = 0.0005$). We derived the regression line equation **$Y = K + b1 \times X$**, based on which we constructed the unique formula for the upper part of the greater sciatic notches calculation.:

$$\mathbf{I=K + (s \times \overline{AC})}$$

I – index of the upper part of the greater sciatic notch

K – constant: 0.098

s – constant: 0.026

$\overline{AC}$ – width of the upper part of the greater sciatic notch

Using this formula, the indexes of the upper part of the greater sciatic notch were calculated and the obtained results were compared with previously obtained index results calculated using previously known formula:

$$\mathbf{I}=\frac{\overline{AC}}{\mathbf{CD}}(20)$$

There was no statistically significant difference between the two methods of calculating the index of the upper part of the great sciatic notch (Table 4).

Table 4. Comparison of two methods of calculating the index of the upper part of the great sciatic notch

	N	Mean	Std. Deviation	Std. Error Mean	p
Index of the upper part of the great sciatic notch calculating by formula $\mathbf{I}=\frac{\overline{AC}}{\overline{CD}}$	98	0.6936	0.178	0.01798	0.098
Index of the upper part of the great sciatic notch calculating by formula $\mathbf{I=K + (s \times \overline{AC})}$	98	0.7053	0.168	0.01701	

IV. DISCUSSION

When using hip bone for gender determination, many parameters can be used with certain degree of accuracy. The hip bone is one of the bones that is the best for that purpose, especially if it is articulated in a complete pelvis with the sacrum, when it becomes details rich source for gender determination. This research was based on osteometric observation of only a few of these parameters that were considered to be the most specific for gender determination. We observed greater sciatic notch, it's depth and width, upper part of its width while the index of the upper part of the greater sciatic notch was calculated from these data. The distribution of osteometric parameters was monitored according to gender, determined on the basis of the index of the upper part of the greater sciatic notch, and according to the left and right hip bone, as well as in the total sample. Our results correlate well with the results of Jovanovic et al. Compared to our results, there are differences in the average values of the width of the greater sciatic notch on the male hip bones (53.94 mm and 57.8 mm), and slightly smaller differences on the female bones (60.65 mm and 58.3-58.5 mm). The reason for this difference could probably be found in the fact that the tip of the ischial spine was used as the front border of the greater sciatic notch, and in our research the base of the same [20].Dnyanesh et al. obtained lower values of width in their study compared to our results, because they took piriform tubercle and the tip of ischial spine as starting points [10].

In our study, the depth of the greater sciatic notch had mean of 33.50 mm (26-42 mm) in the total sample, for male hip bones the mean value was 33,47 mm (26 - 42 mm) and for female hip bone the mean value was 33.55 mm (26 - 40 mm), without statistically significant difference between the gender (p = 0.9). The gender was determined by the index of the upper part of the greater sciatic notch. There was also no statistically significant difference in the depth of the greater sciatic notch comparing right and left hip bone (p = 0.3), where the mean value on the left one was3.18 mm (26 - 41 mm), and on the right one was 33.91 mm (26 - 42 mm). The results of the study by Jovanovic et al. showed slightly higher values of the depth of the greater sciatic notch for both gender, compared to our results. Results of Jovanovic et al, were 39.5 mm on the right hip bone for male and 36 mm on the female hip bones while on the left side the mean value was 39.8 mm for male and 36.8 mm for female hip bones [20]. Akshaya K et al.in a study conducted on 60 pelvic bones originating from India used Vernier calipers to measure the distance between the posterior inferior iliac spine and ishial spine and the depth of sciatic notch. They found that there were sex differences in analyzed parameters and concluded that the distance between posterior inferior iliac spine and ishial spine was greater in the female pelvis while the depth of the sciatic notch was greater in the male pelvis [21]. As in our stady, Soltani S et all. researched gender hip bone dimorphism on iranian population using 237 pelvic CT images (121 women and 116 men) in which the width, depth and posterior segment of the sciatic notch were measured using a digital measuring instrument with a measurement accuracy of 0.01mm. The results of the study showed that there was no sex difference in the depth of the sciatic notch. The posterior angle and posterior segment of the sciatic notch showed statistically significant sex differences [22].In the total sample of the hip bones regardless of gender, the width of the upper part of the greater sciatic notch in our study had mean value 23.36 mm (7 - 48 mm). For male hip bones mean value was 19.57 (7 - 28 mm) and for females mean value was 28.85 mm (20 - 48 mm), with a statistically significant difference between the gender (p = 0.0001). In the total hip bones sample there was no statistically significant difference in the width of the upper part of the greater sciatic notch by comparing the right and left hip bones (p = 0.9). The values obtained in our study were somewhat lower compared to the values from the study of Jovanovic et al. As in our study, no statistically significant difference was found in the width of the upper part of the greater sciatic notch by comparing right and left hip bones, but unlike our results, there was no statistical difference by comparing the male and female hip bones [20]. Antony et al. on a total from 40 hip bones showed that width of the greater sciatic notch is significantly larger in female hip bones when compyred to that of male bones. The depth of the greater sciatic was significantly larger in males when compared to females. The average value of the lenght and depth of the greater sciatic notch was 4.83 for the right and 3.71 for the left side of the pelvis [23]. Prasad et al. study confirmed that greater sciatic notch is the most accuarte method by which gender could be determinated. In their study mean value of the width of greater sciatic notch in female hip bones were 4.69±0.792 for right hip bones and 4.59±0.84 for left ones. For male hip bones mean width was on right hip bones was 3.72±0.45 and for left hip bones mean widht was 3.34±0.51 [24].

The index of the upper part of the greater sciatic notch in the total sample in our study had mean value 0.69 (0.21 - 1.26), for male hip bones index mean value was 0.58 (0.21 - 0.70), and for female hip bones index mean value was 0.86 (0.71 - 1.26). Comparing the arithmetic means of the index of the upper part of the greater sciatic notch between the male and female, we found a statistically significant difference ($p = 0.0001$), without statistically significant difference between arithmetic means of the right and left hip bones ($p = 1$). With this result, we confirmed the importance of calculating the value of the index of the upper part of the greater sciatic notch in determining the gender of the hip bones, and as well as its practical application, which was presented in previous studies [10, 20, 25]. The limit value of the index of the upper part of the greater sciatic notch is predefined as in a previous studies [20], and the data presented above are of a statistical nature, and show us the movements of the index within the male and female gender and their average values. Maximum width of the greater sciatic notch was found to be significantly higher in females (10.5 cm) comapred to males (9.5 cm) in a study of Narwani et al. Index of the greater sciatic was significantly higher in males (62.11±11.2) compared to females (57.71±7.66) (p value 0.047) [26]. A cross sectional study from Soltani et al. on CT scanes on 237 cases (121 females nad 116 males) showed that depth of the gretaer sciatic notch had no difference among males and females, on both right and left sides ($p=0.767$ and $p=0.561$, respectively), and thus it was not useful in gender determination. But greater sciatic notch was significantly wider in females than males ($p<0.001$). Also, index of the greater sciatic notch was significantly different in male and female ($p<0.001$). Mean value for index of greater sciatic notch for right and left male hip bones were 115.64±26.47 and 111.24±24 respectively, 123.84±18.98 and 124.52±20.47 for right and left female hip bones, respectively. There was no significantly difference in index value between right and left hip bones in total ($p=0.377$) [22].

Thus, the above data suggest that statistically significant differences exist in the overall width of the greater sciatic notch and the width of the upper part of the greater sciatic notch between male and female hip bones (gender defined based on the index of the upper part of the greater sciatic notch). Differences in the depth of the greater sciatic notch, within our sample, between male and female bones are not statistically significant. Analysis of pelvic sexual dimorphism was also performed on a sample from Indian population. In Purohit et all. study on a sample of 57 pelvic bones, the authors analyzed sexual differences in pelvic bone using weight, width and length, and sexual differences in the pelvic index. The authors concluded that the mean values of pelvic bone weight were larger in men than in women, while the mean weight of the right pelvic bones were lower in both gender than the mean weight of the left bones. The mean values of pelvic bone length and width on the left side were higher than on the right side. The coxal index was higher in the male pelvis compared to the coxal index in the female pelvis [27].

In our study of all three measured parameters on the hip bones, the width of the upper part of the greater sciatic notch was in the highest correlation with the obtained indices ($r = 0.928$; $p = 0.0005$). Therefore, we derive the linear regression equation $Y = K + b1 \times X$. The results with this equation are almost identical with the results obtained by the formula given above from the literature; for the depth of a greater sciatic notch, difference was only 0.0117, which is not statistically significant ($p = 0.098$). We consider this result very significant. We cannot compare it with literary novelties, since such a model (formula) for calculating the index of the upper part of a greater sciatic notch has not been described. So, we recommended assessment of our model on hip bone of known sex.

Finally, we conclude that in our overall sample there were no statistically significant differences between the right and left hip bones, in terms of osteometric characteristics. Some studies consider that it is important to take into consideration the age of skeleton when determining the gender using the hip bones.. In our study, this was limitation, since the pelvises and isolated hip bones were originated from adults of unknown age.In anatomical - anthropological analyses of the human skeleton, it is important to keep in mind numerious transitional forms in gender prediction, which can range from hyperandroid to unandroidal type for males, and from hyperginoid to unginoid type for females [28]. Therefore, osteometric - quantitative studies are more objective in their approach, and for these reasons we decided to apply this methodology. One of the studies on the hip bones used five parameters for which exact models of how they should look like were determined. Based on appearance, these parameters were classified into three groups: male, female, and transitional form. This methodology excluded the subjective component, thus reducing the possibility of the occurrence of bias. The following parameters were observed: preauricular surface, greater sciatic notch, composite arch, lower pelvic edge, ischiopubic proportion. For each of these parameters, a schematic universal male or universal female form suitable for long-term longitudinal studies were determined, and thus classified them into either category. In case the form would not coincide with any of the offered universal forms, it was classified in an indefinite form or transitional. Based on the processed data, gender prediction was with 95% accuracy [29]. Precisely, a number of authors use classical morphometry [10, 30, 31] to predict gender based on the pelvis and hip bone, which was our as well.The establishment of population standards in gender determination is also of great importance [32]. A study done in Nigeria on 518 pelvises of different age from 17 to 78 years showed that differences in the obtained parameters cannot be taken as relevant for proving gender, and suggested extended research considering other climates and results comparation. [33]. Formulas of discriminant functional analysis for the prediction of gender dimorphism between, for example, African Americans and Americans of European origin populations are less accurate when applied to Population other than one for which they were created [32]. Adherence to population standards is the guarantor of the most effective anthropological evidence and as such is recommendation for forensic medical expertise based on the human skeleton [32], which we were guided by in our study since it was the pelvis and hip bones of the Bosnian population.

V. CONCLUSION

The width of the upper part of the great sciatic notch is the most pronounced parameter in determining the index of the upper part of the great sciatic notch on the basis of which the gender of the coxae is determined. For calculateing the index of the upper part of the great sciatic notch we are free to recommend the regression line equation Y = K + b1 x X is useful, on the basis of which the formula $I = K + (s \times (\overline{AC}))$ is obtained.

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