Size and Form of Human Sternum — Sexual Differences (Osteological Investigation)

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The aim of this study is to make detailed metric characterization of sternum, to establish the sexual differences of separate features and to determine these features, which could give new additional information for sexual determination by bone remains. The anthropological investigation was done on osteological material from archaeological excavations of two mediaeval necropolises. Totally 141 human sterna (75 of male skeletons and 66 of female skeletons) were investigated. Eleven metric features were measured; seven indexes and Durwald's indicator for sex determination were calculated. The quantitative assessment of sexual differences was made by Wolanski's index for inter-group comparisons. It was established that all measured features show priority for male sterna. According to the indices about form and proportionality, the male sternum is relatively longer with shorter *manubrium sterni* being narrower and having thicker basis and with longer and narrower *corpus sterni*, compared to the female one.

Key words: sternum, metric feature, sexual differences.

Introduction

The metric investigation of postcranial skeleton bones has primary meaning for their anthropological characterization and could be applied in other scientific fields as anatomy, clinical medicine, forensic medicine, and archaeology. The results obtained from anthropometric examination of human bones contribute to the determination of sex, age, stature, physical proportionality, etc. in buried individuals. These data enable to get an idea for the physical aspect of respective individual, while still living.

Among bones of postcranial skeleton, the sternum is one of these that contribute to the determination of sex and age. From the commonly accepted anthropometrical features of this bone, like sexual distinctive until now are used the total length of sternum (Dobryak, Dwight), the lengths of *manubrium sterni* and *corpus sterni* (Dobryak). These features are described in the monograph of A l e k s e e v [3]. After Dobryak the percentage proportion between length of *m. sterni* and length of *c. sterni* is approximately 45% for males and 55% for females. The same author utilize for sexual diagnostics the conversely proportion, as well — length of *c. sterni* towards length of *m. sterni* and according to the index value he gives probability (in %) for affiliations of the investigated sternum in male or female individual. Durwald offered an indicator for sexual determination by sternum. This indicator

is a sum of the measurements from the following five metric features: total length of *sternum* without *processus xyphoideus*, breadth of *c. sterni* between junctions for 2nd and 3rd ribs, breadth of *c. sterni* between junctions for 3rd and 4th ribs, least thickness of *m. sterni* in the middle plane and thickness of *c. sterni* in the middle of first segment between junctions for 2nd and 3rd ribs. If the sum from these measurements is above 225 mm, the sternum is male, and if the sum is less than 223 mm — the sternum is female.

The skeleton bones from archaeological excavations are not presented in full strength always. In cases, when cranium and pelvis are missing, or their characteristics do not allow exactly sexual determination, the attention must be directed to the other skeleton bones, which likewise give information about the sex. By this reason, the revealing of new features for sexual distinction, which allow sexual determination in strongly fragmentary or poorly presented bone remains, has own place and importance in the osteometric investigations.

The aim of this study is to make a detailed metric characterization of sternum, to establish the sexual differences of separate features and to determine these features, which could give new additional information for sexual determination by bone remains.

Material and Methods

The anthropological investigation was done on osteological material from archaeological excavations of two mediaeval necropolises from northeastern Bulgaria — Odurtsi and Drustur, dated 10th-11th century AD and 9th-15th century AD respectively. In total, 75 male sterna and 66 female sterna were investigated. The sex and age were determined by metric and scopic features of cranium and postcranial bones, described by M a r t i n – S a l l e r [1], A l e k s e e v [3], N i k i t y u k [4], etc.

The anthropometrical investigation was done by the classical methods of Martin — Saller and Alekseev. Eleven metric features were measured; seven indices and Durwald's indicator for sexual determination were calculated.

The metric data were statistically analyzed using SPSS version 13.0. The established sexual differences were evaluated by the Student's t-test at $p<0.05$. The quantitative assessment of sexual differences was made by Wolansky's index for inter-group comparisons [2]. The index is used to determine the sexual differences and is called Index for Sexual Differences (ISD):

$$ISD = \frac{2.(x_1 - x_2).100}{x_1 + x_2},$$

where x_1 — mean value in males; x_2 — mean value in females.

The intensity of sexual differences was assessed by percentile analysis, according to the data of ISD, and the values of P_{25} (P_{25}= 3.57 IU) and P_{75} (P_{75}= 8.20 IU) were accepted as border limits. The sexual differences are slight at ISD less than 3.57 IU, the differences are moderate at values between 3.58 IU and 8.20 IU, and they are strong at values more than 8.21 IU.

Results and Discussion

Metric characterization

The main biostatistician results of the study are given in Table 1.

T a b l e 1. Biostatistical characterization of measurements and indices of human sternum, for individuals of both sexes (osteological data)

No after Martin	Features	Male						Female						ISD	t-value
		n	mean	min	max	SD	S_x	n	mean	min	max	SD	S_x		
1	Length of *sternum*	33	156.39	140.00	180.00	11.19	1..95	24	132.83	110.00	156.00	11.72	2.39	8.15	0.000***
2	Length of *m. sterni*	57	53.14	43.50	64.00	5.16	0.68	49	47.44	36.00	80.00	6.06	0.87	5.67	0.000***
3	Length of *c. sterni*	47	106.13	88.00	134.00	11.00	1.60	32	88.84	69.50	107.00	8.99	1.59	8.87	0.000***
4	The greatest breadth of *m. sterni*	56	65.83	46.50	87.00	8.10	1.08	50	55.84	45.00	70.00	5.92	0.84	8.21	0.000***
6	The least breadth of *m. sterni*	55	23.53	13.00	36.00	5.04	0.68	47	19.39	10.50	31.00	4.10	0.60	9.65	0.000***
7	Thickness of *m. sterni*	54	12.84	9.00	17.50	1.81	0.25	48	10.48	7.50	13.00	1.39	0.20	10.12	0.000***
5	The greatest breadth of *c. sterni*	44	45.40	28.00	61.00	7.25	1.09	31	41.05	30.00	61.00	8.16	1.47	5.03	0.021*
-	Breadth of *c. sterni* between 2nd and 3rd *i. costales*	54	29.02	23.50	38.50	3.33	0.45	51	25.11	19.00	37.00	3.63	0.51	7.22	0.000***
-	Breadth of *c. sterni* between 3rd and 4th *i. costales*	55	32.15	23.00	43.50	4.36	0.59	46	29.45	20.50	45.00	5.52	0.81	4.38	0.009**
-	The least thickness of *m. sterni*	56	9.50	7.00	12.50	1.16	0.16	50	7.86	5.00	10.00	1.14	0.16	9.45	0.000***
-	Thickness of *c. sterni* between 2nd and 3rd *i. costales*	52	9.27	7.00	12.00	1.29	0.18	47	8.45	5.50	10.00	1.07	0.16	4.63	0.001***
2:1	Lengthwise index of *m. sterni*	33	34.81	26.47	42.36	3.32	0.58	23	35.91	26.62	41.23	3.17	0.66	-1.56	0.217
3:1	Lengthwise index of *c. sterni*	33	68.16	61.81	76.76	3.20	0.56	23	65.83	61.40	68.59	2.31	0.48	1.74	0.003**
5:1	Lengthwise - breadthwise index of sternum	31	29.51	21.60	39.58	4.16	0.75	20	30.19	21.43	43.03	5.80	1.30	-1.14	0.649
5:3	Lengthwise - breadthwise index of *c. sterni*	43	42.55	30.60	64.77	7.92	1.21	26	45.62	31.91	70.00	9.19	1.80	-3.48	0.165
7:6	Breadthwise - corpulence index of *m. sterni*	51	57.91	33.33	111.54	15.56	2.18	46	56.58	27.59	100.00	15.15	2.23	1.16	0.671
-	2:3	33	51.34	34.48	68.54	6.85	1.19	22	55.43	47.66	67.14	5.77	1.23	-3.83	0.021*
-	3:2	33	198.32	145.90	290.00	28.02	4.88	22	182.16	148.94	209.80	17.83	3.80	4.25	0.012*
-	Durwald's indicator	31	238.13	211.00	273.50	14.45	2.60	23	202.17	175.00	246.50	17.36	3.62	8.17	0.000***

*–statistically significant differences at the 0.05 level; **–statistically significant differences at the 0.01 level; ***–statistically significant differences at the 0.001 level.

The basic metric feature of sternum is its total length (1). The measurements of this feature are significantly greater ($P<0.001$) in male sterna than in female ones. The mean difference between both sexes is 23.56 mm.

The sternum is metrically characterized by two other lengthwise features — length of *manubrium sterni* (2) and length of *corpus sterni* (3). The measurements of both features are significantly greater ($P<0.001$) in male sterna, and the male-female difference is 5.70 mm for the first feature and 17.29 mm for the second feature.

The metric characterization of *manubrium sterni* includes two breadthwise features. They are: the greatest breadth (4) and the least breadth (6). The measurements of these features are also significantly greater ($P<0.001$) for the sterna in male individuals compared to these in female individuals. The sexual difference is 9.99 mm for the greatest breadth of *m. sterni* and it is 4.14 mm for its least breadth.

The next two features characterizing *manubrium sterni* are measured in plane perpendicular to the plane of the previous features' measurement. The first is the thickness of *m. sterni* in its basis (7) and the second is its least thickness. Both features are significantly greater ($P<0.001$) in male sterna — with 2.88 mm for the thickness of *m. sterni* in its basis and with 2.31 mm for its least thickness.

Corpus sterni is metrically characterized by three breadths and one thickness, except its length. The greatest breadth of *c. sterni* (5) shows sexual differences in its measurements and they are statistically significant at $P<0.05$. This breadth is greater in male sterna with 4.35 mm.

The other two breadthwise features of *corpus sterni* — its breadth between 2nd and 3rd *incisurae costales* and its breadth between 3rd and 4th *incisurae costales* — are again with metric priority for male sterna, respectively with 3.91 mm and 2.70 mm. The male-female difference is statistically significant at $P<0.001$ for the first feature and at $P<0.01$ for the second one. The differences established show that *corpus sterni* in its upper end is narrower in female sterna, but the measurements of the following breadths in length of *corpus sterni* are closer in both sexes and the sexual differences decrease.

The thickness of *corpus sterni* between 2nd and 3rd *incisurae costales* is significantly greater ($P<0.001$) in male sterna (with 0.82 mm), compared to that in female sterna.

Index characterization about form and proportionality of sternum

The lengthwise index of *manubrium sterni* (2:1) determines the relative percentage of *manubrium sterni* length from the total length of *sternum*. The index is greater in female sterna with 1.10%, compared to this one in male bones. This difference shows relatively longer *m. sterni* in females in comparison with its length in males.

The lengthwise index of *corpus sterni* (3:1) determines the relative percentage of *corpus sterni* length from the total length of *sternum*. The index is significantly greater ($P<0.01$) in male sterna with 2.33%, which shows that *c. sterni* is relatively longer in them, compared to *c. sterni* in female sterna.

The lengthwise – breadthwise index of *sternum* (5:1) determines the proportion of greatest breadth of *c. sterni* towards total length of *sternum*. This index is greater in female sterna with 0.68%. The result means that female sterna are relatively shorter and they have wider *c. sterni* in comparison with male sterna.

The lengthwise – breadthwise index of *corpus sterni* (5:3) determines the proportion of greatest breadth of *c. sterni* towards its length. This index is greater in female sterna again, but with 3.07%, and it shows relatively shorter and wider *c. sterni* in female sterna compared to male ones, too.

The breadthwise – corpulence index of *manubrium sterni* (7:6) determines the proportion between thickness in its basis and its least breadth. The index is greater in male

sterna with 1.33%. This result shows that *manubrium sterni* in males have relatively narrower and thicker basis in comparison with its basis in females.

The next two indices — 2:3 and 3:2, and the Durwald's indicator are confirmed methods for the determination of sexual affiliation by *sternum.*

The results obtained in this study for the first index (for male sterna — 51.34%, for female sterna — 55.43%), show higher index values for male sterna than the data given in literature, while the values for female sterna are more close to them. This exceeding of the values in male sterna, investigated by us, shows that their *manubrium sterni* is comparatively longer from *manubrium sterni* in the male sterna, whose data are given in literature. Although, the difference between both sexes is statistically significant ($P<0.05$).

The index 3:2 has mean values 198.32% for males and 182.16% for females. These values fall into the borders of two near-by rubrics, as the chance about *sternum*'s belonging to one of both sexes within due limits does not exceed 60%. Yet, the sexual difference for this index is statistically significant ($P<0.05$).

The results from Durwald's indicator in this study show that the indicator has lower values in contrast to the author's values at 19.36% of the male sterna (6 from 31 sterna) and having higher values at 13.04% of the female sterna (3 from 23 sterna). The difference between mean values in males and females is statistically significant at very high level ($P<0.001$). This result confirms the probability for using the Durwald's indicator as an accessory factor about sexual diagnostic.

Comparative assessment of sexual differences by the data of ISD

The differences between both sexes for all investigated metric features are evaluated in comparative plan by the calculation of ISD. It is meant by the unmeasured quantities of ISD to show up the features with greatest importance for the sexual differentiation.

It is established, that all measured features show priority for male sterna (Fig. 1). Strongest sexual differences display both measured features of *m. sterni* in its basis — the thickness of *m. sterni* in its basis (10.12 IU) and the least breadth of *m. sterni* (9.65 IU). Other features with strong sexual differences are: the least thickness of *m. sterni* (9.45 IU), the length of *c. sterni* (8.87 IU) and the greatest breadth of *m. sterni* (8.21 IU). Therefore strongly sexual differences are marked for two from three measured thicknesses. Differences between both sexes from a moderate strength are reported for the following features: total length of *sternum* (8.15 IU), breadth of *c. sterni* between 2nd and 3rd *incisurae costales* (7.22 IU), length of *m. sterni* (5.67 IU), greatest breadth of *c. sterni* (5.03 IU), breadth of *c. sterni* between 3rd and 4th *incisurae costales* (4.38 IU) and thickness of *c. sterni* between 2nd and 3rd *incisurae costales* (4.63 IU). Slightly sexual differences are not recorded for any of the features.

Three indices about form and proportionality show priority for female sterna, but the sexual differences in them are slightly pronounced — lengthwise - breadthwise index of *c. sterni* (3.48 IU), lengthwise index of *m. sterni* (1.56 IU) and lengthwise - breadth wise index of *sternum* (1.14 IU). The indices, which ISD values display priority for male sterna, are: lengthwise index of *c. sterni* (1.74 IU) and breadthwise - corpulence index of *m. sterni* (1.16 IU), as the sexual differences for each one of them are slight.

Indices 2:3 and 3:2 have values of ISD respectively — 3.83 IU and 4.25 IU and they show moderate sexual differences. The ISD value of Durwald's indicator is 8.17 IU, which mean that the sexual differences for this indicator are moderate too, but it has greater importance for the sexual differentiation in contrast to the aforesaid two indices.
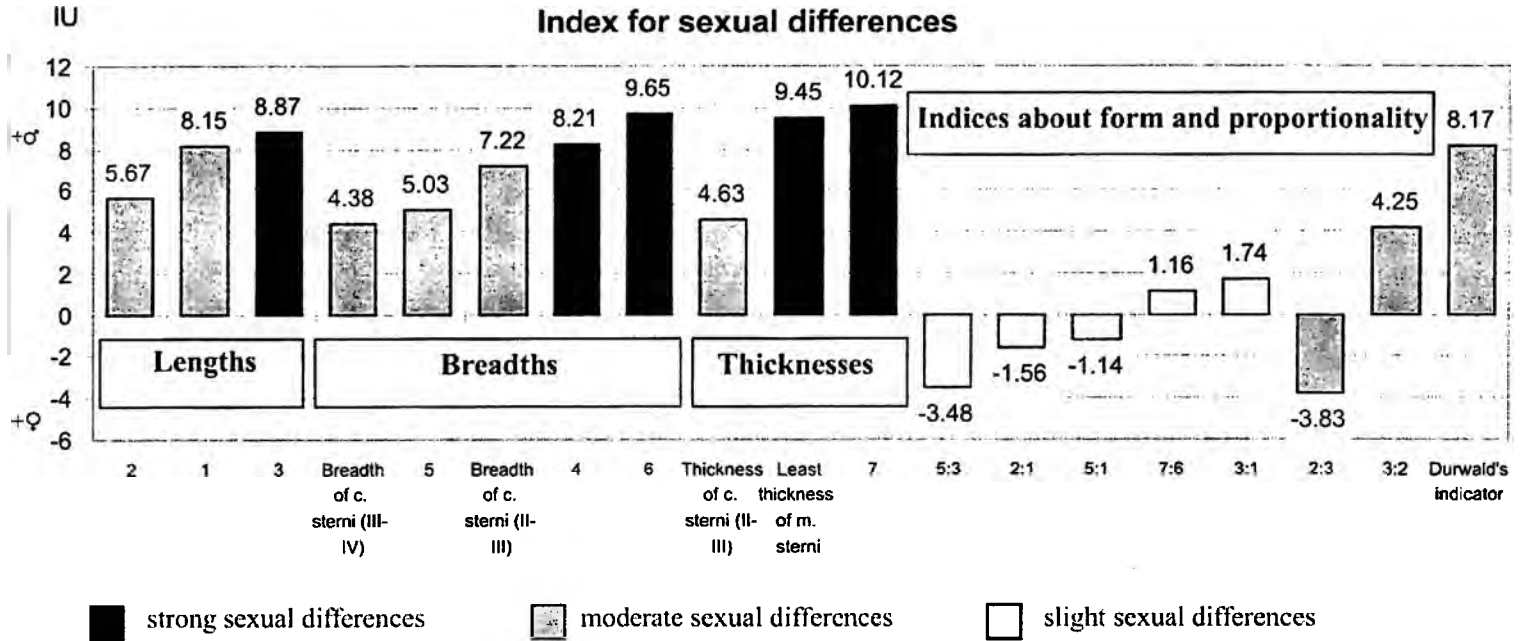
Index for sexual differences

Fig. 1. Values of ISD about measurements and indices of sternum

Discussion

The results obtained provide a possibility to make some conclusions for the measurements and proportionality of sternum in both sexes.

The generalized metric characterization of sternum shows that:

– among basic lengthwise features, the total length of *sternum*, as well as the lengths of *manubrium sterni* and *corpus sterni* are greater in males;

– *manubrium sterni* in male skeletons is emphatically wider and with greater thickness, compared to that in female ones;

– *corpus sterni* in male sterna is comparatively wider and with greater thickness, compared to the corpus in female sterna.

The sexual differences for all 11 investigated metric features are statistically significant, as the level of significance for 9 of them is very high — $P<0.001$. These results confirm the possibility for using the sternum' measurements to elaborate prognostic markers for the determination of sexual affiliation of buried individuals.

The index characterization about form and proportionality shows that male sterna have shorter *manubrium sterni* and longer and narrower *corpus sterni*, while in female sterna *manubrium sterni* are longer and *corpus sterni* are shorter and wider. The lengthwise index of *corpus sterni* (3:1) displays statistically significant differences between both sexes at $P<0.01$, and confirms it as witness for the sexual differences in sternum form.

In connection with the results from data analysis for lengthwise – breadthwise index of sternum (5:1) and lengthwise - breadthwise index of *corpus sterni* (5:3) could be note that *corpus sterni* in males have greater absolute breadthwise measurements, but female sterna as a form are relatively wider because of the less length of *corpus sterni* in them.

The results from ISD data analysis lay the following inferences to be made:

Among the confirmed methods for sexual diagnostics after sternum, Durwald's indicator is the better one from the other indices for that purpose — 2:3 and 3:2.

Each five from all direct measured features have higher ISD values than the Durwald's indicator. They are: thickness of *m. sterni* in its basis, least breadth of *m. sterni*, least breadth of *m. sterni*, length of *c. sterni* and greatest breadth of *m. sterni*. On the basis of their data after purposeful investigations could be elaborated additional indicators for the distinction of sternum in both sexes.

The lengthwise – breadthwise index of *c. sterni* (5:3) has ISD value near to the indices confirmed for this purpose (2:3 and 3:2). It shows that this index could be used for sexual diagnostics by sternum, as well. As an example we could say that values less than 42.6% are a sign for male sex and values more than 45.6% are a sign for female sex.

Conclusions

All measured features of *sternum* — lengths, breadths and thicknesses, show metric priority for the sternum of male skeletons.

According to the indices about form and proportionality, male sterna are relatively longer with shorter *manubrium sterni* being narrower and having thicker basis and with longer and narrower *corpus sterni*, compared to female sterna

The comparative assessment of sexual differences by ISD shows that sterna in both sexes are strongly differentiated by: thickness of *m. sterni* in its basis, least breadth of *m. sterni*, least breadth of *m. sterni*, length of *c. sterni* and greatest breadth of *m. sterni*. Largest meanings for the sexual determination among indices about form and proportionality have the lengthwise — breadthwise index of *corpus sterni*.

Our results show that in case of surely determined sex on bone remains by cranium, pelvis and so on, the sternum distinctly confirm the established sexual affiliation, as well. This result in own turn allows using the sternum as a reliable additional indicator for the determination of sex in investigated skeletal remains.

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