A METRIC METHOD FOR SEXING ATLAS AND AXIS VERTEBRAE IN MAN

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INTRODUCTION

The assessment of sex in most of the individual bones of the skeleton, especially in the vertebrae, appears to be uncertain. It is not unusual for the workers engaged in anthropological studies or in medico-legal practice to be confronted with problems of diagnosing the sex of isolated bones (Warwick and williams, 1973). The known criteria adopted in sexing skulls or pelvic bones cannot be applied with certainty in case of vertebrae.

Review of the available literature concerning the sex differences in the atlas and axis vertebrae reveals a great gap in knowledge. Francis (1955), however, had contributed to this field by using groups of vertebrae with known sex.

The present work is, therefore, an endeavour to find out a metrical method for demonstrating sexual differences in a mixed collection of human atlas and axis vertebrae.

MATERIALS AND METHODS

Series of 138 atlas and 136 axis vertebrae of unknown sex and belonging to adult contemporary Egyptians were collected for the present study from tombs with mass burial. The following measurements were taken in these vertebrae using a sliding caliper :

Atlas vertebrae :

— The maximal distance between the tip of the right and left transverse processes (TA).

— The maximal distance between the outer borders of the right and left superior articular processes (SA).

— The minimal distance between the anterior ends of the right and left superior articular processes (MA).

— The transverse diameter of the vertebral foramen between the medial edges of the right and left

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superior articular facets opposite the tubercles for the attachment of the transverse ligament of the atlas (TT).

— The maximal distance between the outer borders of the right and left inferior articular processes (IA).

Axis vertebrae :

— The maximal distance between the tips of the right and left-transverse processes (TX).

— The maximal distance between the outer borders of the right and left superior articular processes (SX).

— The minimal distance between the anterior ends of the right and left superior articular processes (MX).

— The maximal distance between the outer borders of the right and left inferior articular processes (IX).

In addition, for the purpose of comparison, the maximal breadth of the foramen magnum was measured in 146 skulls which were collected from the same tombs along with the vertebrae examined. The whole material, therefore, could be presumed to belong to the same group of individuals. The total number of skulls collected was 170, but only 146 skulls were found suitable for taking such measurements. These skulls were sexed by anatomical appreciation and were found to be 77 males and 69 females.

All measurements were taken to the nearest millimetre, and therefrom necessary graphs were constructed.

RESULTS

The graph for the bitransverse diameter of the atlas vertebrae reveals two peaks at 71—72 mm and 77—78mm with a depression in between the two peaks at 73—74 mm (fig. 1 a). Analysis of the frequency of vertebrae at the site of the depression between the two peaks shows the bitransverse diameter of 75 m in 13 cases, 73 mm in 6 cases and 76 mm in 9 cases. The graph for the bitransverse diameter of the axis vertebrae also shows two main peaks at 48—49 mm and 56—57mm, in addition to a smaller intermediate peak at 52—53 mm (fig. 1 b). Herein, the frequency of cases at the site of the intermediate peak shows the bitransverse diameter of 52 mm in 13 vertebrae, 51 mm in 5 vertebrae and 53 mm in 9 vertebrae.

Furthermore, the atlas vertebrae lying opposite the bitransverse diameter of 75 mm had the measurements between the outer borders of their inferior articular processes (IA) ranging between 40 mm and 47 mm with the median value in between 43 mm and 44 mm. These findings are also obtained for the measurements between the outer borders of the superior articular processes of the axis vertebrae (SX) lying opposite the bitransverse diameter of 52—53 mm.

Comparison between atlas vertebrae and skulls :

The graphs in respect of the measurements taken on the atlas vertebrae and the foramen magnum show that the females are always smaller in their measurements than the males, and consequently they are shifted more to the left side of the graphs. The difference between the number of males and females on either side of the graph is taken as a criterion for comparison. The point of intersection between the male and female curves is the limit between the two sides of the graph. The difference reveals an excess of 15 females on the left side and 34 males on the right side of the graph for the distance between the outer borders of the right and left superior articular processes of the atlas vertebrae (fig. 2). In the graph for the distance representing the transverse ligament of the atlas vertebra (TT) the difference shows an excess of 14 females on its left side and 33 males on its right side (fig. 3 b). As regards the foramen magnum breadth of the skulls examined, the difference reveals an excess of 22 females and 30 males on the left and right sides of the graph respectively (fig. 3 a).

It is also noticed that the two peaks of the measurements of the foramen magnum breadth of the male skulls lie at 30 mm and 32 mm while the two peaks of the distance representing the transverse ligament of the male atlas vertebrae (TT) are present opposite 26 mm and 28 mm. The difference between the two peaks in each graph is only one point of 2 mm.

Comparison between atlas and axis vertebrae :

The graph for the distance between the outer borders of the right and left inferior articular processes of the atlas shows an excess of 37 females on the left side of the graph and 58 males on its right side (fig. 4 b). Similarly, the dimension between the outer borders of the right and left superior articular processes of the axis vertebrae demonstrates a difference of 39 females and 67 males on the left and the right sides of the graph respectively (fig. 4 a). It is obvious that the amount of difference between both sexes on either side of each of these graphs is marked, and consequently the overlap is lesser than the corresponding difference recorded for the graph of the foramen magnum breadth or that for the distance between the outer borders of the superior processes of the atlas vertebae. The arithmatic mean of the distance between the outer borders of the inferior articular processes of the atlas is found to be 46.54 mm in males and 42.94 mm in females. These results are nearly equal to the means obtained for the distance between the outer borders of the superior articular processes of the axis which are 46.46 mm for males and 42.28 mm for females (table 1).

The degree of difference between the male and female means varies from one measurement to the other in both atlas and axis vertebrae. This is clear from the results of application of the «t-test» which demonstrates that the most significant difference exists for the bitransverse diameter of both the atlas and axis vertebrae as well as for the maximum distance between the outer borders of the inferior articular processes of the axis vertebrae. However, the distance between the anterior ends of the superior articular processes of the atlas and the corresponding distance between the superior articular processes of the axis have the least significant sexual difference (table 2 and figs. 5 a & b).

DISCUSSION

It is a common anatomical experience that the male bones, in general, are larger in size than the corresponding female bones. The present authors, therefore, expected likely manifestations of sexual difference in the bitransverse diameters of the atlas and axis vertebrae. It was deduced from the graphs made for these diameters that each peak represented the mode of either the male or the female measurements with the site of overlap lying opposite 75 mm for the atlas and at 52—53 mm for the axis vertebrae. Borderline cases between males and females were sorted out as males or females according to the measurements taken between the outer borders of the inferior articular processes of the atlas or those between the outer borders of the superior articular processes of the axis vertebrae. In respect of the measurements that have been already mentioned, the borderline cases of both the atlas and the axis vertebrae showed a range of 40 - 47 mm with a median value lying between 43 mm and 44 mm.

Accordingly, it was assumed that an atlas vertebra might be identified as a male vertebra if it possessed a bitransverse diameter larger than 75 mm and as a female vertebra if this diameter was less than 75mm. In case the bitransverse diameter was borderline i.e., equals 75 mm, the atlas was considered as a male one if the distance between the outer borders of its inferior articular processes was 44 mm or more; and as a female one if it was less than 44 mm. Likewise, an axis vertebra was sexed as a male if its bitransverse diameter exceeded 53 mm and as a female if it was less than 52 mm. An axis vertebra having a bitransverse diameter of 52 or 53 mm was identified as a male when the distance between the outer borders of its superior articular processes was 44 mm or more, and as a female when it was less than 44 mm.

Sexing atlas vertebrae by the above-mentioned method resulted in a sex ratio very close to the ratio obtained for the axis vertebrae as well as for the skulls examined, all of which belonged to the same individuals. This result revealed absence of significant difference between the metrical method used in sexing the vertebrae and the descriptive method applied in sexing the skulls.

Another evidence that substantiated the validity of the present method of sexing came from the similarity in the patterns of the male and female curves as seen in the graphs for the foramen magnum breadth and those for the atlas vertebrae. A further support was obtained from the fact that inspite of the difference in the length of the bitransverse diameters of the atlas and the axis vertebrae and consequently both the vertebrae being sexed differently, the arithmatic mean of the diameters between the outer borders of the inferior articular processes of the male atlas vertebrae was found equal to that of the corresponding diameters between the superior articular processes of the male axis vertebrae. The same results were also found for the female groups of both types of vertebrae. However, the diameter between the outer borders of the inferior articular processes of the atlas has been found, in a previous work, to be nearly equal to the diameter between the outer borders of the superior articular processes of the axis vertebra belonging to the same individual (Gaballah et al, 1978). Obviously, any error in sexing either group of atlas and axis vertebrae would have resulted in a marked difference between the respective means.

Comparison with the results given by Francis (1955) on the cervical vertebrae of American whites and Negroes, whose sex was known from the records, revealed much resemblence with the present findings. The Egyptian material, however, possessed an intermediate position between the two American groups. Cyriax (1920) has provided measurements of an unsexed series of cervical vertebrae but he stated that «the greater number of bones were from male subjects». The data of Cyriax for the bitransverse diameter (78.07 mm for the atlas and 54.49 mm for the axis) were found very close to those recorded for the present male vertebrae. The present observations corroborated those of Cyriax (1920) and Francis (1955), and this might be regarded as an additional support for the validity of the metrical method of study in sexing the upper two cersexing the upper two cervical vertebrae.

It has been demonstrated that not every measurement showed the same degree of sex difference. This was clearly evident in case of the bitransverse diameter which revealed the maximal sex difference, whereas the distance between the anterior ends of the superior articular processes showed the least significant sex difference. Consequently, the bitransverse diameter will show the least overlap between sexes and an attempt was made to calculate the degree of this overlap. The ranges reported by Francis (1955) on a material with definitely known sex were used for this purpose. It was concluded that 64% of the atlas and 55% of the axis vertebrae showed the same measurement of the bitransverse diameter in males as in females. Therefore, it remains only about 36% of the atlas and 45% of the axis vertebrae that lie outside the limits of overlap between males and females and could be sexed with a higher degree of confidence. This was attained by applying the confidence interval of the computed mean (mean ± three times its standard error).

As far as the present material is concerned, it is most probable for an isolated atlas vertebra to be sexed male if it possesses a bitransverse diameter of more than 80.20 mm, or sexed female if the diameter is less than 71.09 mm. Likewise, an axis vertebra may be diagnosed as a male if its bitransverse diameter is more than 56.86 mm or as a female if it is less than 49.32 mm.

SUMMARY

A series of atlas and axis vertebrae belonging to human subjects of unknown sex was collected for the determination of their sex by a metrical method. This method was based on the consideration of the bitransverse diameter and the maximal distance between the articular processes. Graphs as well as statistical parameters of the data for each sex were provided. It was concluded that an atlas vertebra could be sexed male if its bitrasverse diameter exceeded 80.20 mm or be a female if it was less than 71.09 mm. Using the same measurement, an axis vertebra could be a male if its bitransverse diameter exceeded 56.86 mm or a female if it was less than 49.32 mm.

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TABLE 1

Measurements of atlas and axis vertebrae

Diameters of atlas	N	Range	MALES Mean ± S.E.	N	Range	FEMALES Mean ± S.E.
TA	79	(75) — 88	79.78 ± 0.14	59	65 — (75)	71.42 ± 0.11
MA	79	14 — 24	18.18 ± 0.07	59	12 — 21	17.18 ± 0.06
IA	80	41 — 53	46.54 ± 0.06	59	38 — 47	42.94 ± 0.08
SA	79	40 — 57	47.98 ± 0.14	60	39 — 53	42.50 ± 0.12
Diameters of axis						
TX	82	(52) — 65	56.68 ± 0.09	54	43 — (53)	49.68 ± 0.12
MX	83	10 — 19	13.98 ± 0.04	54	11 — 18	13.33 ± 0.05
IX	74	45 — 55	49.18 ± 0.08	52	40 — 49	44.96 ± 0.09
SX	82	41 — 52	46.46 ± 0.05	54	54 — 49	42.28 ± 0.08

The values between brackets represent the borderline between both sexes as shown in the relevant graphs (figs. 1 & b).

TABLE 2

Significance of differences between both sexes using «t-test» at p=0.05

Diameters of atlas	t-test	Diameters of axis	t-test
TA	16.1 (H.S.)	TX	15.6 (H.S.)
MA	2.7 (J.S.)	MX	2.2 (J.S.)
IA	9.7 (H.S.)	IX	9.8 (H.S.)
SA	3.8 (S.)	SX	12.3 (H.S.)

H. S. = highly significant difference.
J.S. = Just significant difference.
S. = Significant difference.

EXPLANATION OF FIGURES

Fig. (1 a) : A graph for the maximal bitransverse diameter (TA) of the atlas vertebrae of both sexes mixed together.

Fig. (1 b) : A graph for the maximal bitransverse diameter (TX) of axis vertebrae of both sexes mixed together.

Fig. (2) : A graph for the maximal distance between the outer borders of the right and left superior articular processes (SA) of atlas vertebrae.

Fig. (3 a) : A graph for the breadth of the foramen magnum.

Fig. (3 b) : A graph for the transverse diameter of the vertebral foramen between the medial edges of the right and left superior articular facets (TT) of atlas vertebrae.

Fig. (4 a) : A graph for the maximal distance between the outer borders of the right and left superior articular processes of the axis vertebrae (SX).

Fig. (4 b) : A graph for the maximal distance between the outer borders of the right and left inferior articular processes of atlas vertebrae (IA).

Fig. (5 a) : A graph for the minimal distance between the anterior ends of the right and left superior articular processes of axis vertebrae (MX).

Fig. (5 b) : A graph for the minimal distance between the anterior ends of the right and left superior articular processes of atlas certebrae (MA).

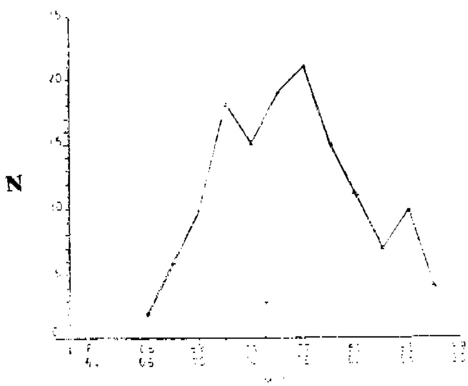
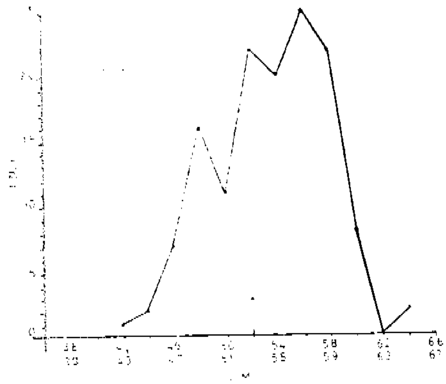


Fig. (1. a)



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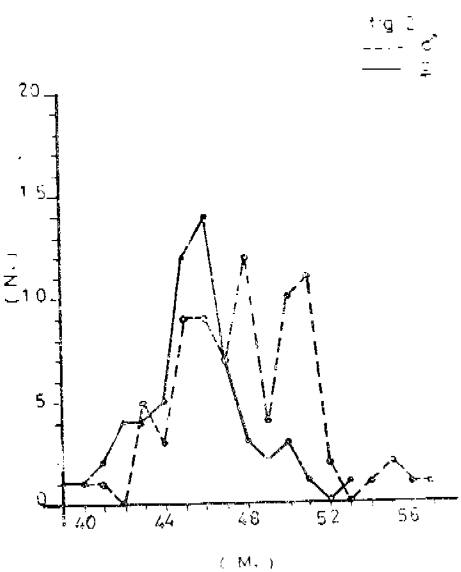

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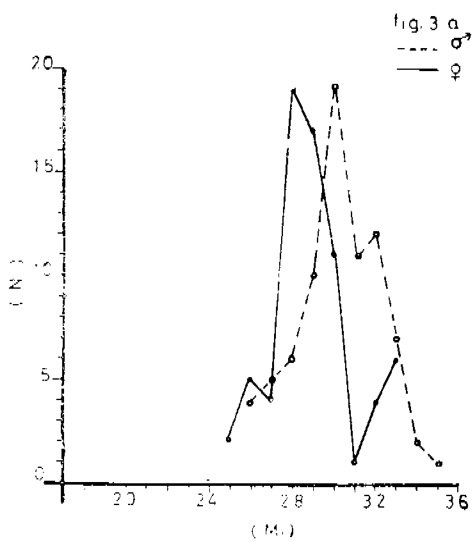
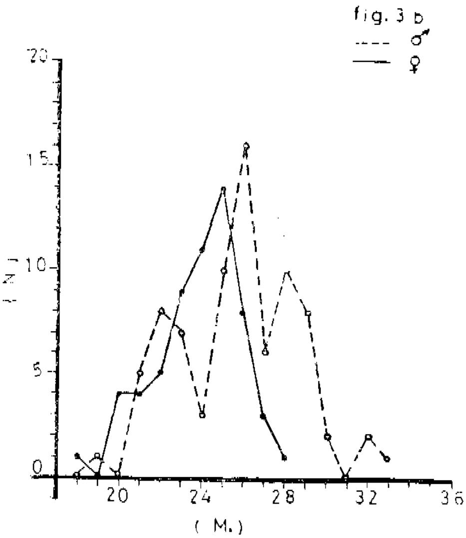


Fig. (3. a)



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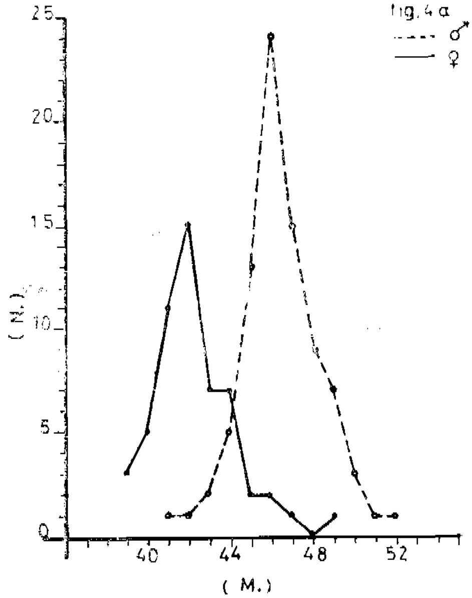

Fig. (4. a)

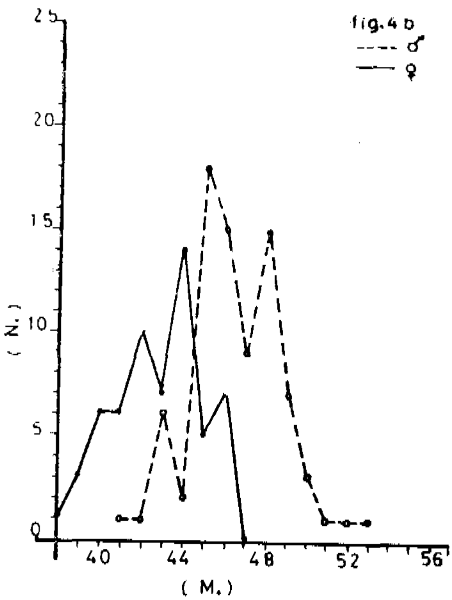

Fig. (4. b)

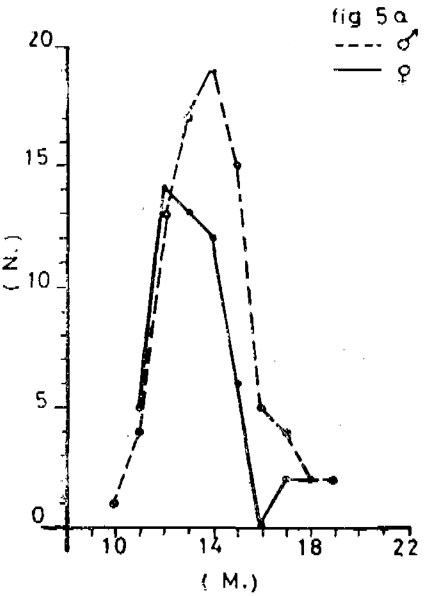

Fig. (5. a)

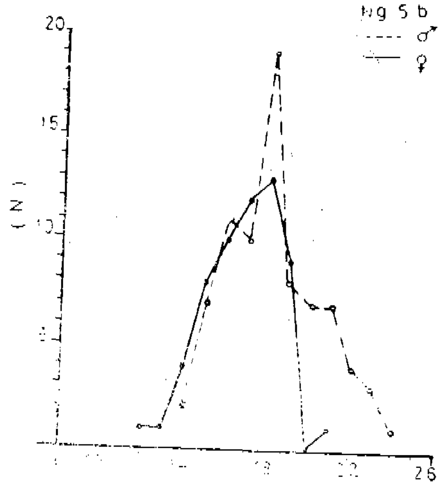

Fig. (5. b)