THE ATLAS AND AXIS IN CHINESE

By J. K. Woo

Introduction. Atlas and axis are the first two peculiar vertebrae of the vertebral column. Macalister(1), Ossenfort(2) and other early workers had reported their comparative anatomical features and made a few observations and measurements. This problem, however, is by no means extensively studied as the other bony elements and it is still far from complete especially in the metric characters. As to the Chinese material, only Haberer(3) had given a very brief description on a few Peking specimens. The object of the present study is to provide some basic data of the metrical and non-metrical characters of the Chinese specimens.

Description of material. Atlas is the first cervical vertebra supporting the globe of the head. It has no body which has fused with that of the next vertebra——the axis to form the odontoid process. It consists of an anterior and a posterior arch connected by two lateral masses. The anterior arch is short and with convex surface, while the posterior one is long and ends behind in the posterior tubercle. The axis or epistropheus is the second cervical

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(1) a. Macalister, A., "Notes on Homologies and Comparative Anatomy of the Atlas and Axis" *Journal of Anatomy and Physiology*, London, III, 54-64, 1869.

b. ——, "The Development and Varieties of the Second Cervical Vertebra" *Journal of Anatomy and Physiology*, London, XXVIII, 257, 1894.

(2) a. Ossenfort, W. F., "The Atlas in Whites and Negroes" *American Journal of Physical Anthropology*, IX 439-443, 1926.

b. ——, "Variations of the Atlas in Whites and Negroes" *Anatomical Record*, XXXII, 239, 1926.

(3) Haberer, K. A., *Schaedel und Skeletteile aus Peking*, Jena, 120-130, 1902.

vertebra which forms the pivot upon which the atlas rotates Its chief peculiarity is the odontoid process ——a strong and cylindrical process rising perpendicularly from the upper surface of the body. The main part of the material dealt with here was collected in 1938 from Lien Hua Ch'ih, Kunming. The specimens of the atlas include 72 males and 40 females, and those of the axis 82 males and 37 females. All are well-preserved and sufficiently complete to give all the measurements described in the following section. More than 80 % of the specimens in both cases belong to the same individuals. Besides, two ancient Chinese series are added for comparison. The first series includes 41 specimens of the Yin Dynasty from Hou Chia Chuang of Anyang Hsieu, and the second, 9 of the Sui-T'ang Dynasties from Hsiao T'un of the same district.

Measurements and indices. The following measurements are all taken with the sliding caliper. Readings of the linear ones are to the nearest of 1.0 mm.

a. Measurements of atlas:

1. maximum length (Fig. 1, AB)[1]
2. Maximum breadth (Fig. 1. CD)[1]
3. Maximum vertical height of the anterior arch
4. Meximum vertical height of the posterior arch
5. Maximum height[2]

This was measured with the superior articular processes firmly against the fixed jaw of the sliding caliper and the movable jaw tracing the maximum height on the inferior articular processes.

6. Distance between the front ends of the two superior articular surfaces (Fig. 1, EE')
7. Distance between the hind ends of the two superior articular surfaces (Fig 1, FF')
8. Angle formed by the extending lines of the maximum lengths of the two superior articular surfaces (Fig 1. θ)

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1. After R. Martin, Lehrbuch der Anthropologie. Jena, 1928.
2. After Ossenfort, *loc cit.* a.

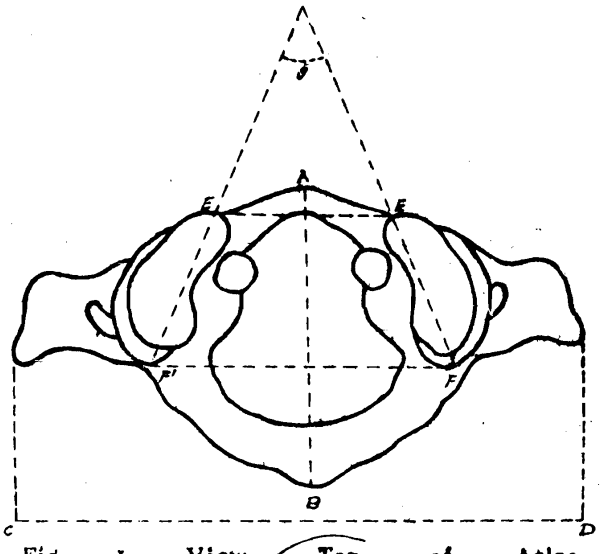

Fig I View Top of Atlas

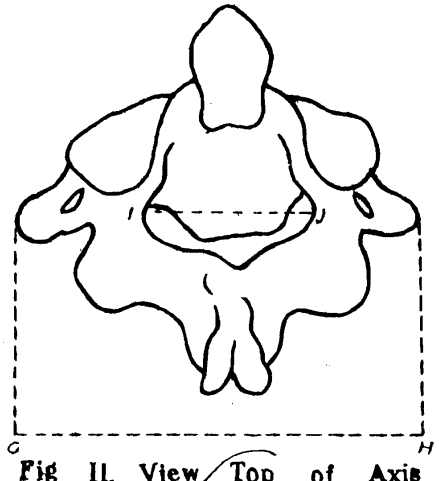

Fig II. View Top of Axis

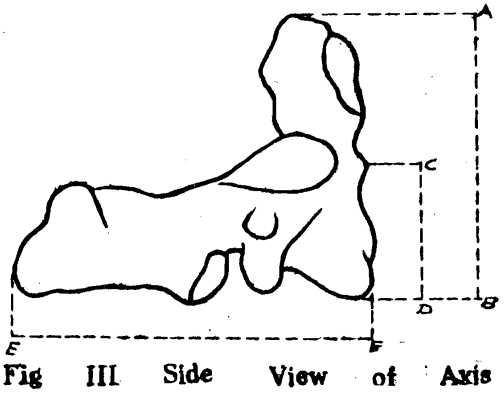

Fig III Side View of Axis

Method: Fix one silk thread at two ends above a piece of glass and place the specimen on the glass with the line of the maximum length of the left (or right) superior articular surface coinciding with the thread. Then the angle is measured by a transparent protractor on which one scale line coincides with that of the maximum length of the right (or left) superior articular surface. The center of the protractor should be always kept on the thread.

b. Measurements of axis:

1. Maximum height (Fig. III, AB)[1]
2. Height of the body (Fig, III, CD)[2]

This is taken from the mid-point of the ridge where the odontoid process ends to the lowerest point of the axis body, i. e ., the height excluding the odontoid process.

3. Maximum length (Fig. III EF)[1]
4. Maximum breadth (Fig. GH)[1]
5. Sagittal length of the vertebral foramen[1]
6. Thansverse breadth of the vertebral foramen Fig. II, IJ)[1]

c. Indices of atlas:

1. $\frac{\text{Maximum length [1]} \times 100}{\text{Maximum breadth [2]}}$
2. $\frac{\text{Maximum vertical height of posterior arch [4]} \times 100}{\text{Maximum vertical hight of anterior arch [3]}}$
3. $\frac{\text{Maximum height [5]}^2 \times 100}{\text{Maximum length [1]}}$
4. $\frac{\text{Distance between front ends [6]} \times 100}{\text{Distance between hind ends [7]}}$

d. Indices of axis:

1. $\frac{\text{Height of the body [2]} \times 100}{\text{Maximum height [1]}}$
2. $\frac{\text{Maximum length [3]} \times 100}{\text{Maximum breadth [4]}}$

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1. After Martin, *loc .cit.*
2. After Cssenfort, *loc .cit.*

3. $\frac{\text{Sagittal length of vertebral foramen [5]}}{\text{Transverse breadth of vertebral foramen [6]}} \times 100$

The figure in the square brackets indicates the number of measurements described above.

Metric characters. The means and standard deviations of the measurements and indices are given in the accompanying tables I & II. Owing to the slenderness of adequate comparative materials, we have to restrict our consideration, both sexual and racial, to the material available at hand.

Judging from the present data, the absolute characters of the male specimens are all larger than those of the female, except in the case of one angular measurement formed by the extending lines of the maximum lengths of the two superior articular facets of the atlas. In particular, the maximum lengths and breadths and the heights of the two bones show a remarkable sexual difference. They may be of some use for the purpose of sexual identification. The sexual differentiation of the relative characters or indices in all cases is not so significant as the absolute ones except in the case of the second index of the atlas.

Now we will proceed to discuss and compare the feature of a few metric characters of these two bones between different sets of materials available.

(a) Distances between the ends of the superior articular surfaces of the atlas and the angle formed by the extending lines of their maximum lengths.

As shown in the table below, the mean value of the two distances of the modern Chinese series is intermediately placed between the two ancient series. Their differences, however, are not great. The mean angle for the Yin Dynasty is the smallest probably due to the fact that the front ends distance of the

Series	Cases	Front ends distance (mm)	Hind ends distance (mm)	Angle
Ancient Chinees (Hou Chia Chuang)	41	18.85	41.28	54°.5
Ancient Chinese (Hsiao T'un)	9	17.24	39.22	60°.2
Modern Chinese (Kunming)	108	18.37	40.04	60°.4

said series is much greater. The difference, nevertheless, between average angles of the two ancient series is significant.

Macalister[1] has fonnd in one hundred European specimens that the distance between the front ends of the two articular surfaces varies from 10-20 mm., being usually from 15-20 mm., and that the hind ends are from 32-50 mm. apart, the greater number being separated from 35-40 mm. The angle formed in the way as described above ranges from 32°-63°. In our Chinese series the distances between both the front ends and hind ends have much wider ranges. The variability of the angular character of the Chinese series seems to be greater than that for the Europeans.

(b) The length height index of the atlas.

The length height index is defined to be:

$$\frac{\text{Maximum height [5]} \times 100}{\text{Maximum length [1]}}$$

The mean indices and their ranges for the three Chinese series as well as for Ossenfort's Whites and Negroes series are provided in the following table.

Series	Cases	Range	Index
Negroes	81	37-59	48
Whites	102	38-64	49
Ancient Chinese (Hsiao T'un)	9	40.14-54.12	49.30
Ancient Chinese (Hou Chia Chuang)	39	40.22-57.31	49.76
Modern Chinese (Kunming)	110	40.14-69.41	50.26

It is of interest to note that the mean indices for the three Chinese series are all higher than those for the series of Whites and Negroes, although the mean of the Hsiao T'un series approaches to that of the Whites. It means that the Chinese atlas is higher and broader in shape. The distinction between the Whites and Negroes in this respect is not great.

1. From George A., Piersol, Human Anatomy, 120, 1923.

(c) Heights of the axis.

Series	Cases	I	II	I—II	II×100/I
		Maximum height (cm)	Body height (cm)	Height of odontoid process	Height Index
Ancient Chiese (Hou Chia Chuang)	42	3.69	1.83	1.86	49.92
Ancient Chiese (Hsiao T'un)	14	3.72	1.87	1.85	50 18
Modern Chinese (kunming)	114	3.62	1.98	1.64	53.99

The values of the two ancient series has no great difference as shown in the table. The difference, however, between the ancient and the modern is significant. Among the three series the maximum height of the modern Chinese is the smallest and its body height the greatest. Accordingly, the modern series has the least height of odontoid prodess and the largest height index.

Non-metric characters. This part of study was based only on the material of the modern Chinese series.

(a) Prominence of the anterior and posterior tubercles of the atlas.

For the purpose of comparison, the degree of prominence of the anterior and posterior tubercles of this bone is arbitrarily classified into four grades: (1) traceable, (2) slight, (3) medium and 4) marked. The percentage values of prominence for both sexes are given below;

Anterior tubercle					
Sex	Cases	Traceable	Slight	Medium	Marked
♂	72	12.50	27.78	37.50	22.22
♀	44	25.00	27.27	36.36	11.36
Posterior tubercle					
Sex	Cases	Traceable	Slight	Medium	Marked
♂	71	23.94	19.72	35.21	21 13
♀	44	31.82	31.8	27.27	6.82

It shows clearly from the above table that the percentages of the 'marked' grade in the male are much higher than those of the similar grades in the female. In other words, the tubercle of the female specimen is less prominent both anteriory and posteriorly as anticipated.

(b) Form of the fovea dentis of the atlas

On the posterior side of the anterior arch of the atlas, a smooth, round or oval facet is presented known as the fovea dentis which articulates with the odontoid process of the axis. Out of the 72 male specimens, 87.5 per cent are found to be round in form, while out of the 43 female ones, 90.7 per cent are round. In both sexes the percentage of the oval form is considerably small.

(c) Form of the articular facet of the odontoid process of the axis.

For simplicity, the form of the articular facet of this bone is merely noted as being 'oval' or 'round'. It is curious to see that a high percentage of this feature is found in the oval form instead of the round one (75.9% for the male and 70.3% for the female). As the articular facet of the odontoid process is closley articulated with the fovea dentis of the atlas, different forms of these two facets may be accounted for by a mechanical factor. It wonld be easier to render the atlas performing a freely rotating movement of the head, when the form of the first facet appears to be round and that of the second oval.

(d) Form of the apex of the odontoid process of the axis

The form of the apex of this process may be conveniently divided into three classes, namely 'single', 'bifid' and separate nodule'. The percentage distribution of the three forms for this feacture is presented in the table below.

Sex	Chinese	Single	Bifid	Separate nodule
♂	83	74.70	14.46	10.84
♀	37	59.46	27.03	13.51

It is clear that the dominent type is found in the 'single' form, 74.7 per cent in the male and 59.5 per cent in the female. Sexual differentiation of this feature apperars to be more marked.

Summary. 231 specimens of the atlas ans axis of modern Chinese collected in Kunming were examined. In addition 50 ancient specimens from Anyang Hsien of Honan were used for comparison. 8 measurements and 4 indices were taken on the atlas, and 6 measurements and 3 indices on the axis. Judging from the absolute characters the sizes of the male are always greater with the exception of one angular measurement taken on the atlas. The typical shape of the Chinese atlas is clearly different from that of both Whites and Negroes. The Chinese specimen is higher and broader. Both anterior and posterior tubercles of the Chinese atlas are prominent, especially in the male specimens. The fovea dentis of the same bone is dominent in the round form. In the case of the axis the modern Chinese series has smaller maximum height and greater body height than the ancient ones. The articular facet of the odontoid process is usually found to be oval and its apex frequently in the 'single' form. In several cases the sexual difference of morphorogical characters is less marked.

TABLE I. Means and standard deviations of the measurements of atlas and axis (in cm.)

Measurements	Cases		Range		Mean		Standard deviation	
	♂	♀	♂	♀	♂	♀	♂	♀
Atlas								
Maximum length	72	40	3.89-5.01	3.44-4.64	4.40±.013	4.10±.028	.23±.013	.26±.020
Maximum breadth	68	39	6.06-8.63	6.04-3.02	7.42±.047	6.82±.051	.58±.033	.47±.036
Anterior height	71	40	.86-1.46	.76-1.21	1.13±.010	1.00±.011	.13±.007	.10±.008
Posterior height	69	37	.54-1.22	.61-1.31	.93±.012	.90±.021	.15±.009	.13±.015
Maximum height	70	40	1.85-2.73	1.61-2.46	2.23±.017	1.98±.017	.21±.012	.16±.012
Hind ends dist.	68	40	2.82-5.01	3.30-4.74	4.05±.033	3.95±.033	.40±.023	.31±.023
Front end dist.	68	40	.90-2.71	1.29-2.54	1.90±.028	1.73±.029	.34±.020	.27±.021
Angle	68	40	37.1-85.5	43.5-82.5	53.4±.545	63.8±.945	6.66±.385	8.36±.668
Axis								
Maximum height	80	34	3.21-4.29	2.97-4.16	3.74±.017	3.50±.031	.23±.012	.27±.022
Body height	80	34	1.66-2.43	1.54-2.13	2.04±.011	1.85±.016	.15±.008	.14±.011
Maximum length	66	27	1.81-5.40	3.67-4.76	4.67±.035	4.27±.043	.42±.025	.33±.030
Maximum breadth	67	30	4.49-6.51	4.21-5.79	5.35±.037	5.00±.042	.45±.026	.34±.030
Leng. of vert. for.	76	36	1.50-2.35	1.59-2.09	1.97±.004	1.85±.012	.05±.003	.11±.009
Bread. of vert. for.	81	37	1.91-2.56	1.83-2.49	2.23±.010	2.17±.016	.14±.007	.11±.011

TABLE II. Means and standard deviations of the indices of atlas and axis.

Indices	Cases		Range		Mean		Standard deviation	
	♂	♀	♂	♀	♂	♀	♂	♀
Atlas								
1.	68	39	48.81-71.45	50.93-70.53	59.63±.416	60.22±.426	5.09±.294	3.94±.321
2.	69	36	45.53-127.03	51.67-128.26	85.11±.1.159	90.13±.1.875	14.28±.820	16.68±1.326
3.	70	40	40.56-69.41	40.14-57.21	51.30±.404	48.43±.427	5.00±.286	4.00±.302
4.	68	40	17.96-70.21	33.76-61.21	47.34±.666	43.98±.784	8.31±.471	7.35±.554
Axis								
1.	80	34	41.20-62.62	46.29-53.77	54.41±.242	53.00±.368	3.21±.171	3.18±.260
2.	64	26	63.49-101.13	68.32-97.02	87.17±.637	85.60±.935	7.79±.465	7.45±.696
3.	76	36	65.79-102.34	63.47-98.51	87.68±.552	85.23±.755	7.14±.390	6.72±.534