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Strong Covariation Between Costal Chord and Cranial Length: Toward the Solution of the Brachycephalization Problem

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Abstract Using principal component analysis (PCA) and Kaiser's normal varimax rotation method, the relations of three main neurocranial measurements with those of the sternum and ribs were examined as a step toward finding the causes of brachycephalization. In result, the data of females showed that the principal component or rotated factor significantly correlated with cranial length was also correlated with the costal chords of at least the first to the seventh rib. This suggests that the anteroposterior diameter of the thorax may be associated with the formation of the cranial structure. It remains to be solved, however, whether these correlations are biomechanically caused by the posture of the body or produced by the pleiotropic genes which were rigidly fixed in our ancestral population in considerably ancient times.
Key words: Brachycephalization, Neurocranium, Sternum, Ribs, Principal component analysis

Toward finding the causes of brachycephalization, Mizoguchi (1992) made a preliminary analysis of the relations of three neurocranial measurements, *i.e.*, cranial length and breadth and basi-bregmatic height, with those of other parts of the body. Since this preliminary analysis suggested that the neurocranial measurements might be relatively highly correlated not only with the size of jaws but also with some postcranial measurements, he started to analyze the relations between the cranial measurements and those of other bones in more detail. Up to the present, Mizoguchi (1994, 1995, 1996, 1997, 1998a, b) has finished a series of multivariate analyses on all the vertebrae but the coccygeal. The main findings in these analyses are that cranial length is strongly correlated with the size of the vertebral body throughout almost all vertebrae (Mizoguchi, 1997, 1998a), and with the superior and middle breadths of the sacrum (Mizoguchi, 1998a, b).

In the present study, the correlations between the three main neurocranial measurements and those of the sternum and ribs are examined in the same way as in the above studies.

Materials and Methods

The data on the neurocranium published by Miyamoto (1924) and those on the

Table 1. Means and standard deviations for the measurements of the sternum in Japanese males and females.[1)]

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
1	Length of sternum	4	148.5	10.5	14	117.1	12.7
2	Length of manubrium	4	46.3	4.6	14	42.6	4.4
3	Length of body	5	103.2	7.4	14	76.6	13.3
4	Maximum breadth of manubrium	4	59.0	4.4	14	49.7	3.9
5	Maximum breadth of body	5	36.2	3.0	14	30.2	3.9
K-7	Max. br. at up. border of 4th cost. notch	5	32.8	3.6	14	28.4	4.0
K-8	Max. br. between 4th and 5th cost. notches	5	35.8	3.0	13	29.1	4.9
6	Minimum breadth of manubrium	4	33.5	1.3	14	27.2	4.0
K-10	Min. br. between 2nd and 3rd cost. notches	5	25.4	3.0	14	22.8	3.5
7	Thickness of manubrium	4	11.0	0.8	14	10.1	1.8
KKa-12	Sternal angle (in degree)[3)]	4	18.5	5.4	14	18.1	6.5

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Kikitsu (1930a).

[2)] Variable number according to Martin and Saller (1957) except for those with the letter 'K' preceding the number, which are measurement item nos. of Kiyono's (1929) measurement system, and for those with the letters 'KKa' preceding the number, which are measurement item nos. in Kikitsu (1930a).

[3)] No definition is given for this item in Kikitsu (1930a).

sternum and the right ribs reported by Kikitsu (1930a, b) were used for the present analyses. These are of the same individuals, *i.e.*, 30 male and 20 female Japanese from the Kinai district. The basic statistics for the measurements of the sternum are listed in Table 1, those of the ribs are in Tables 2 and 3, and those for the neurocranium are presented in Mizoguchi (1994). As shown in these tables, the samples of both sternum and ribs from males were too small to analyze in the following multivariate analyses. Therefore, only the data of females were used in such analyses. But even the female samples were very small from the viewpoint of the statistical limitation on sample size and the number of variables. Thus, two multivariate analyses were carried out for each sample using two different sets of variables the number of which was smaller than the number of individuals.

For examining the overall relationships between the measurements, principal component analysis (Lawley and Maxwell, 1963; Okuno *et al.*, 1971, 1976; Takeuchi and Yanai, 1972) was applied to the correlation matrices. In the present study, the number of principal components was so determined that the cumulative proportion of the variances of the principal components exceeded 80%. The principal components obtaind in such a way were then transformed by Kaiser's normal varimax rotation method (Asano, 1971; Okuno *et al.*, 1971) into different factors, which may suggest

Table 2. Means and standard deviations for the measurements of the right ribs in Japanese males.[1)]

Variable[2)]		1st rib			2nd rib		
		n	Mean	SD	*n*	Mean	SD
3	Arc	6	128.8	6.6	6	207.8	12.6
4	Chord	6	67.7	2.4	6	96.3	4.6
1	Maximum height about the middle	6	4.7	0.5	6	6.0	1.4
K-4	Maximum height at anterior end	6	9.2	0.8	6	6.7	0.5
KKb-3C	Height at costal angle		—		6	7.5	0.5
KKb-3D	Height at neck	6	4.8	0.4	6	6.5	0.5
2	Thickness at the middle of body	6	15.7	1.5	6	14.5	3.1
KKb-4B	Thickness at anterior end	6	17.0	1.1	6	12.0	0.6
KKb-4C	Thickness at costal angle		—		6	12.5	1.6
KKb-4D	Thickness at neck	6	6.5	1.4	6	6.8	1.2
KKb-5A	Circumference at the middle of body	6	36.3	1.8	6	37.3	3.5
KKb-5B	Circumference at anterior end	6	43.0	1.7	6	30.7	1.2
KKb-5C	Circumference at costal angle		—		6	34.5	2.9
KKb-5D	Circumference of neck	6	21.2	2.9	6	24.0	2.8
K-6	Length of neck	6	26.5	2.4	6	26.0	2.4
KKb-7	Subtense	6	43.3	2.9	6	71.3	3.6
KKb-8	Costal angle (in degree)		—			—	

Table 2. (Continued)

	3rd rib			4th rib			5th rib			6th rib		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
3	6	254.5	14.9	6	283.8	10.6	6	299.3	10.0	6	303.0	12.8
4	6	125.8	6.4	6	151.7	7.2	6	171.2	9.1	6	181.8	9.7
1	6	13.2	1.2	6	13.5	0.8	6	14.5	1.4	6	13.2	2.2
K-4	6	14.5	1.0	6	15.0	1.1	6	14.3	0.8	6	14.2	1.2
KKb-3C	6	12.2	1.3	6	11.7	1.2	6	12.7	2.3	6	13.7	2.9
KKb-3D	6	8.0	0.6	6	9.8	0.8	6	10.7	0.8	6	11.7	1.0
2	6	5.8	0.8	6	6.3	0.5	6	6.7	0.5	6	7.2	0.8
KKb-4B	6	6.2	0.8	6	7.0	0.0	6	8.2	1.0	6	9.0	0.6
KKb-4C	6	8.3	0.5	6	8.5	0.8	6	8.8	0.8	6	9.2	1.2
KKb-4D	6	5.5	0.5	6	5.3	0.5	6	6.0	0.6	6	5.7	0.5
KKb-5A	6	32.7	1.9	6	34.0	1.4	6	35.7	2.3	6	34.8	2.9
KKb-5B	6	34.5	3.0	6	37.3	3.0	6	37.3	2.7	6	37.7	2.0
KKb-5C	6	33.8	3.0	6	33.3	2.0	6	35.7	3.3	6	37.7	3.4
KKb-5D	6	23.3	1.8	6	26.3	3.3	6	29.5	1.5	6	31.2	2.3
K-6	6	25.5	2.1	6	25.2	1.2	6	25.8	0.8	6	25.8	0.8
KKb-7	6	83.0	3.2	6	86.7	3.8	6	86.8	3.7	6	83.3	4.7
KKb-8	6	85.3	3.8	6	88.5	5.2	6	87.5	4.3	6	90.0	3.2

Table 2. (Continued)

	7th rib			8th rib			9th rib			10th rib		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
3	6	298.0	11.0	6	285.7	9.1	6	269.3	10.9	6	235.3	10.5
4	6	189.7	10.8	6	188.8	12.0	6	179.3	13.1	6	161.0	11.0
1	6	15.5	3.0	6	17.5	3.5	6	18.5	3.0	6	17.2	3.2
K-4	6	15.3	1.2	6	13.2	1.7	6	11.3	0.8	6	11.0	0.9
KKb-3C	6	15.0	2.7	6	16.3	3.0	6	17.3	2.3	6	15.8	2.8
KKb-3D	6	12.7	0.8	6	13.0	0.9	6	13.0	0.9	6	12.2	1.0
2	6	6.8	1.3	6	6.0	1.3	6	5.7	0.8	6	5.0	0.6
KKb-4B	6	8.8	0.8	6	7.8	0.4	6	7.8	0.4	6	6.2	0.8
KKb-4C	6	9.3	1.0	6	8.5	1.0	6	8.0	0.9	6	7.7	1.0
KKb-4D	6	5.8	0.8	6	6.2	1.0	6	6.2	1.2	6	6.3	1.0
KKb-5A	6	38.2	3.1	6	40.3	5.4	6	43.2	4.2	6	39.0	5.6
KKb-5B	6	39.5	1.9	6	34.2	2.9	6	31.5	2.3	6	29.0	3.0
KKb-5C	6	40.0	3.7	6	41.2	4.9	6	42.3	4.4	6	39.8	4.8
KKb-5D	6	33.3	2.3	6	33.5	1.4	6	34.2	1.8	6	32.7	3.4
K-6	6	25.3	1.5	6	23.8	1.5	6	23.5	2.3	3	19.7	0.6
KKb-7	6	78.8	4.0	6	74.5	3.3	6	73.0	3.7	6	65.2	3.4
KKb-8	6	90.8	5.2	6	96.3	6.3	6	100.7	4.9	5	106.0	5.0

Table 2. (Continued)

	11th rib			12th rib		
	n	Mean	SD	*n*	Mean	SD
3	6	182.5	17.8	6	107.3	35.8
4	6	135.7	14.8	6	92.0	28.7
1	6	14.0	2.8	6	12.3	2.1
K-4		—			—	
KKb-3C		—			—	
KKb-3D		—			—	
2	6	4.2	0.8	6	3.5	0.8
KKb-4B		—			—	
KKb-4C		—			—	
KKb-4D		—			—	
KKb-5A	6	32.5	4.7	6	28.2	5.2
KKb-5B		—			—	
KKb-5C		—			—	
KKb-5D		—			—	
K-6		—			—	
KKb-7	6	51.0	5.9	6	25.0	8.0
KKb-8		—			—	

[1] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Kikitsu (1930b).

[2] Variable number according to Martin and Saller (1957) except for those with the letter 'K' preceding the number, which are measurement item nos. of Kiyono's (1929) measurement system, and for those with the letters 'KKb' preceding the number, which are measurement item nos. in Kikitsu (1930b).

Table 3. Means and standard deviations for the measurements of the right ribs in Japanese females.[1)]

Variable[2)]		1st rib			2nd rib		
		n	Mean	SD	*n*	Mean	SD
3	Arc	19	125.3	12.0	19	198.9	10.2
4	Chord	19	65.1	4.3	19	93.7	6.2
1	Maximum height about the middle	20	4.2	0.7	20	5.2	0.6
K-4	Maximum height at anterior end	19	7.3	1.2	19	5.5	0.8
KKb-3C	Height at costal angle		—		20	7.0	0.8
KKb-3D	Height at neck	20	4.4	0.8	20	5.1	0.6
2	Thickness at the middle of body	20	14.1	1.4	20	12.7	2.1
KKb-4B	Thickness at anterior end	19	15.8	1.5	19	10.7	1.1
KKb-4C	Thickness at costal angle		—		20	9.0	1.3
KKb-4D	Thickness at neck	20	6.6	1.4	20	5.6	1.0
KKb-5A	Circumference at the middle of body	20	33.3	3.1	20	31.1	3.6
KKb-5B	Circumference at anterior end	19	40.2	3.1	19	28.2	2.5
KKb-5C	Circumference at costal angle		—		20	29.7	1.8
KKb-5D	Circumference of neck	20	21.2	2.1	20	20.4	1.6
K-6	Length of neck	20	22.8	2.8	20	24.4	1.6
KKb-7	Subtense	19	40.3	4.6	19	66.3	3.4
KKb-8	Costal angle (in degree)		—			—	

Table 3. (Continued)

	3rd rib			4th rib			5th rib			6th rib		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
3	20	243.0	9.2	20	263.0	11.1	18	274.8	8.3	19	274.7	7.0
4	20	123.0	7.5	20	142.3	9.0	18	155.4	9.8	19	163.8	9.1
1	20	10.6	1.5	20	10.5	1.4	20	10.2	0.8	20	10.7	0.9
K-4	20	12.5	1.2	20	12.2	1.5	18	11.8	1.2	19	12.5	1.5
KKb-3C	20	8.9	1.0	20	9.5	0.8	20	11.0	1.4	20	12.0	1.2
KKb-3D	20	6.7	0.9	20	7.8	0.7	20	8.7	0.8	20	9.7	0.9
2	20	4.2	0.5	20	4.8	0.6	20	5.2	0.7	20	5.2	0.8
KKb-4B	20	5.5	1.0	20	5.6	1.0	18	5.9	0.8	19	6.8	1.2
KKb-4C	20	6.7	0.7	20	6.8	0.9	20	7.2	0.9	20	7.4	1.0
KKb-4D	20	4.1	0.7	20	4.4	0.7	20	4.6	0.7	20	4.8	0.6
KKb-5A	20	27.0	2.8	20	27.6	2.4	20	27.7	1.1	20	28.6	1.8
KKb-5B	20	31.3	2.7	20	31.3	3.2	18	31.1	2.5	19	33.4	3.4
KKb-5C	20	27.2	2.3	20	28.4	1.7	20	31.0	2.5	20	33.0	2.1
KKb-5D	20	20.3	1.5	20	22.6	1.2	20	24.7	1.8	20	27.0	1.8
K-6	20	24.0	1.9	20	23.4	2.2	20	23.3	2.1	20	23.1	1.8
KKb-7	20	77.4	3.0	20	80.6	2.9	18	80.5	2.8	19	77.1	3.3
KKb-8	20	78.0	3.8	20	76.5	5.1	20	81.6	4.8	20	86.1	5.1

Table 3. (Continued)

	7th rib			8th rib			9th rib			10th rib		
	n	Mean	SD	*n*	Mean	SD	*n*	Mean	SD	*n*	Mean	SD
3	20	269.1	7.5	20	258.4	7.7	19	240.0	8.0	20	209.5	8.7
4	20	169.6	9.5	20	166.6	8.9	18	156.1	7.9	20	142.5	8.5
1	20	12.2	1.2	20	13.7	1.3	20	14.5	1.6	20	13.4	1.4
K-4	20	13.5	1.7	20	10.8	1.3	20	9.5	1.2	20	8.4	1.2
KKb-3C	20	12.9	1.5	20	14.4	1.9	20	14.6	1.1	20	13.2	1.5
KKb-3D	20	10.5	1.1	20	10.8	1.2	19	10.9	1.4	20	10.3	1.0
2	20	5.4	0.9	20	4.8	1.0	20	4.5	0.7	20	3.8	0.8
KKb-4B	20	7.2	1.3	20	6.8	1.0	20	6.5	1.1	20	5.1	0.8
KKb-4C	20	7.4	1.0	20	6.8	1.0	20	6.6	0.7	20	5.9	0.7
KKb-4D	20	4.9	0.6	20	5.1	0.7	19	5.4	0.7	20	5.4	0.5
KKb-5A	20	31.1	1.9	20	32.9	2.1	20	34.2	3.0	20	31.3	2.8
KKb-5B	20	34.8	4.3	20	29.9	3.2	20	27.5	2.9	20	24.4	2.7
KKb-5C	20	34.4	2.8	20	36.2	3.3	20	36.2	2.0	20	32.6	2.9
KKb-5D	20	28.9	2.1	20	30.0	2.5	19	30.5	3.2	20	28.8	2.5
K-6	20	22.7	1.7	20	22.0	1.9	19	20.7	2.0	12	18.9	1.5
KKb-7	20	72.5	4.0	20	68.8	4.5	19	66.4	3.9	20	59.2	4.0
KKb-8	20	91.0	3.8	20	96.2	4.4	19	101.1	4.5	20	106.0	4.7

Table 3. (Continued)

	11th rib			12th rib		
	n	Mean	SD	*n*	Mean	SD
3	19	158.6	14.1	18	93.8	17.5
4	19	119.6	9.8	18	80.4	14.0
1	20	11.3	1.4	18	9.8	0.9
K-4		—			—	
KKb-3C		—			—	
KKb-3D		—			—	
2	20	3.1	0.3	18	2.8	0.4
KKb-4B		—			—	
KKb-4C		—			—	
KKb-4D		—			—	
KKb-5A	20	26.9	2.6	18	24.0	1.6
KKb-5B		—			—	
KKb-5C		—			—	
KKb-5D		—			—	
K-6		—			—	
KKb-7	19	42.9	4.5	17	21.0	4.2
KKb-8		—			—	

[1] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Kikitsu (1930b).

[2] Variable number according to Martin and Saller (1957) except for those with the letter 'K' preceding the number, which are measurement item nos. of Kiyono's (1929) measurement system, and for those with the letters 'KKb' preceding the number, which are measurement item nos. in Kikitsu (1930b).

some other associations hidden behind the measurements dealt with.

The significance of factor loadings was tested by the bootstrap method (Efron, 1979a, b, 1982; Diaconis and Efron, 1983; Mizoguchi, 1993). In order to estimate the bootstrap standard deviation of a factor loading, 1,000 bootstrap replications including the observed sample were used. The estimation of a bootstrap standard deviation was made by directly counting the cumulative frequency for the standard deviation in the bootstrap distribution.

Regarding the ribs, the reality of such a common factor as represented by a principal component or rotated factor was further examined by finding similarities between the factors obtained from different ribs, *i.e.*, by estimating a Spearman's rank correlation coefficient (Siegel, 1956) between the variation patterns of the factor loadings, though indirectly.

The statistical calculations were executed with the mainframe, HITACHI MP5800 System, of the Computer Centre, the University of Tokyo. The programs used are BSFMD for calculating basic statistics, BTPCA for principal component analysis and Kaiser's normal varimax rotation, and RKCNCT for rank correlation coefficients. All of these programs have been written in FORTRAN by the present author.

Results

Principal component analysis (PCA) was applied only to the female data because the sample sizes for males were too small.

The direct result of the PCA and the rotated solution for the first set of variables of the neurocranium and the sternum are shown in Tables 4 and 5, respectively, and those for the second set, in Tables 6 and 7. None of these analyses showed that there was any principal component (PC) or rotated factor (Fac) which was significantly correlated both with one or more of the cranial measurements and with one or more of the sternal measurements at the 5% level.

Similarly, the results for the skull and the ribs are shown in Tables 8 to 51. The PCs which have significant correlations with both cranial length and some costal measurements are as follows: PC I for the fourth rib, which is correlated with costal arc, costal chord, and the thickness at the costal angle (Table 20); PC I for the sixth rib (the first set of variables), which is correlated with costal chord, the maximum heights about the middle and at the anterior end, and the thicknesses at the middle of the body, at the anterior end, at the costal angle and at the neck (Table 28); PC I for the sixth rib (the second set of variables), which is correlated with the circumferences at the anterior end and of the neck (Table 30); PC I for the seventh rib, which is correlated with costal chord, the maximum height at the anterior end, and the thicknesses at the middle of the body, at the anterior end, at the costal angle and at the neck (Table 32); and PC I for the eighth rib, which is correlated with the circumference at

Table 4. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the sternum from Japanese females.[1)]

Variable[2)]		Factor loadings			Total variance (%)
		PC I	II	III	
1	Cranial length	.59	.51	−.24	66.16
8	Cranial breadth	−.19	−.54	.76	90.35
17	Basi-bregmatic height	−.05	.43	.71	69.94
1	Length of sternum	.88*	−.39	−.07	93.92
2	Length of manubrium	.41	.62	.38	70.21
3	Length of body	.77	−.54	−.18	91.53
4	Max. br. of manubrium	.61	.66	.16	82.10
5	Maximum breadth of body	.55	−.49	.49	78.20
Total contribution (%)		32.52	27.92	19.86	80.30
Cumulative proportion (%)		32.52	60.44	80.30	80.30

[1)] The sample size is 14. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 1.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 5. Solution obtained through the normal varimax rotation of the first three principal components for the correlation matrix on the first set of measurements of the neurocranium and the sternum from Japanese females.[1)]

Variable[2)]		Factor loadings		
		Fac I	II	III
1	Cranial length	.24	.54	−.56
8	Cranial breadth	.08	−.12	.94
17	Basi-bregmatic height	−.31	.63	.45
1	Length of sternum	.96*	.11	−.08
2	Length of manubrium	.00	.84	−.03
3	Length of body	.95	−.11	−.09
4	Max. br. of manubrium	.16	.85	−.28
5	Maximum breadth of body	.70	.14	.52

[1)] The sample size is 14. The cumulative proportion of the variances of the three principal components is 80.30%.

[2)] See the second footnote to Table 1.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 6. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the sternum from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	–.25	.61	–.32	.53	82.95
8	Cranial breadth	.75	–.29	.50	–.07	90.13
17	Basi-bregmatic height	–.09	.07	.82	.51	93.98
K-7	Max. br. at 4th cost. notch	.86***	.34	.04	.03	86.22
K-8	Max. br. between 4th & 5th c.n.	.76**	.35	–.24	.29	83.64
6	Min. br. of manubrium	.71*	.27	–.43	–.07	76.75
K-10	Min. br. between 2nd & 3rd c.n.	.73*	.26	.30	–.23	74.09
7	Thickness of manubrium	–.26	.80*	.43	–.18	92.03
KKa-12	Sternal angle	–.46	.77	.07	–.35	93.32
Total contribution (%)		36.24	23.05	17.18	9.44	85.90
Cumulative proportion (%)		36.24	59.29	76.47	85.90	85.90

[1)] The sample size is 13. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 1.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 7. Solution obtained through the normal varimax rotation of the first four principal components for the correlation matrix on the second set of measurements of the neurocranium and the sternum from Japanese females.[1)]

Variable[2)]		Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.13	.23	.09	.87
8	Cranial breadth	.49	–.27	.35	–.69
17	Basi-bregmatic height	–.07	.09	.96*	–.02
K-7	Max. br. at 4th cost. notch	.91*	.01	.06	–.15
K-8	Max. br. between 4th & 5th c.n.	.88	–.14	–.01	.20
6	Min. br. of manubrium	.78	–.09	–.38	.05
K-10	Min. br. between 2nd & 3rd c.n.	.71	.19	.11	–.44
7	Thickness of manubrium	.05	.92	.26	.10
KKa-12	Sternal angle	–.12	.92	–.12	.23

[1)] The sample size is 13. The cumulative proportion of the variances of the four principal components is 85.90%.

[2)] See the second footnote to Table 1.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 8. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the first rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.44	.66	.24	−.15	−.40	87.75
8	Cranial breadth	−.39	−.52	.57	.24	.28	87.38
17	Basi-bregmatic height	.38	−.11	.68	−.08	.24	68.03
3	Arc	.67	−.17	.10	−.07	.52	76.27
4	Chord	.58	.53	.24	−.35	.14	80.85
1	Max. ht. about middle	.68	−.04	−.05	.61	.06	84.12
K-4	Max. ht. at ant. end	.09	.70	−.18	.55	.19	86.80
KKb-3D	Height at neck	.39	−.56	−.58	.05	−.13	82.34
2	Thick. at mid. of body	.66	−.57	−.09	−.26	−.17	86.50
KKb-4B	Thick. at ant. end	.75	−.12	.03	.18	−.22	66.15
KKb-4D	Thickness at neck	−.05	−.23	.62	.28	−.57	85.05
Total contribution (%)		26.33	20.26	15.30	9.72	9.41	81.02
Cumulative proportion (%)		26.33	46.59	61.89	71.61	81.02	81.02

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 9. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the first set of measurements of the neurocranium and the first rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	−.09	.90	.20	.13	.07
8	Cranial breadth	−.24	−.71	.40	−.13	.37
17	Basi–bregmatic height	−.00	.07	.27	−.02	.78**
3	Arc	.36	.03	−.29	.22	.71*
4	Chord	−.05	.73	−.19	.05	.49
1	Max. ht. about middle	.39	.04	.09	.79	.23
K-4	Max. ht. at ant. end	−.41	.25	−.22	.75	−.15
KKb-3D	Height at neck	.84	−.20	−.18	.11	−.20
2	Thick. at mid. of body	.87	.07	.05	−.14	.27
KKb-4B	Thick. at ant. end	.58	.30	.20	.37	.24
KKb-4D	Thickness at neck	.01	−.03	.92***	−.02	.04

[1)] The sample size is 19. The cumulative proportion of the variances of the five principal components is 81.02%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 10. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the first rib from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.31	.59	.58	.27	86.02
8	Cranial breadth	−.13	−.87	−.04	.29	84.97
17	Basi-bregmatic height	.58*	−.37	.22	.60	88.38
KKb-5A	Circumf. mid. body	.76***	−.31	.13	−.43	87.01
KKb-5B	Circumf. ant. end	.61**	.42	.03	.07	54.89
KKb-5D	Circumf. of neck	.24	−.33	.79	−.29	87.78
K-6	Length of neck	.78**	.16	−.42	.13	83.05
KKb-7	Subtense	.81***	−.17	−.35	−.18	84.00
Total contribution (%)		33.82	20.91	16.74	10.55	82.01
Cumulative proportion (%)		33.82	54.73	71.46	82.01	82.01

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 11. Solution obtained through the normal varimax rotation of the first four principal components for the correlation matrix on the second set of measurements of the neurocranium and the first rib from Japanese females.[1)]

Variable[2)]		Factor loadings			
		Fac I	II	III	IV
1	Cranial length	−.10	.90	.16	.15
8	Cranial breadth	−.12	−.69	.12	.59
17	Basi-bregmatic height	.28	.13	.14	.88
KKb-5A	Circumf. mid. body	.70	−.03	.61*	.05
KKb-5B	Circumf. ant. end	.47	.57	−.02	.04
KKb-5D	Circumf. of neck	−.07	.09	.92	.15
K-6	Length of neck	.82	.24	−.25	.18
KKb-7	Subtense	.91*	−.05	.09	.10

[1)] The sample size is 19. The cumulative proportion of the variances of the four principal components is 82.01%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 12. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the second rib from Japanese females.[1)]

Variable[2)]		Factor loadings						Total variance (%)
		PC I	II	III	IV	V	VI	
1	Cranial length	–.27	–.68	.45	–.09	–.29	.28	90.68
8	Cranial breadth	.07	.14	–.85	–.32	.23	.08	90.64
17	Basi-bregmatic height	.31	–.40	–.18	–.41	.15	.66*	90.62
3	Arc	.75	–.42	.05	–.08	.25	–.17	84.34
4	Chord	.01	–.87	.33	–.02	.21	–.10	92.03
1	Max. ht. about middle	–.83	–.14	–.05	–.04	–.04	–.02	71.51
K-4	Max. ht. at ant. end	–.35	–.09	.47	–.09	.62	–.22	78.87
KKb-3C	Ht. at cost. angle	.38	.14	.07	.61	.48	.34	89.02
KKb-3D	Height at neck	.04	.64	.53	.04	.21	.26	80.23
2	Thick. at mid. of body	–.49	.42	.30	–.06	–.14	.33	63.95
KKb-4B	Thick. at ant. end	–.50	.20	.03	–.54	.45	–.04	78.93
KKb-4C	Thick. at co. angle	–.57	–.46	–.35	.37	.08	.18	83.87
KKb-4D	Thickness at neck	–.55	–.12	–.42	.37	.25	–.01	69.89
Total contribution (%)		21.70	19.07	15.08	9.53	9.35	7.16	81.89
Cumulative proportion (%)		21.70	40.77	55.85	65.38	74.73	81.89	81.89

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 13. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the first set of measurements of the neurocranium and the second rib from Japanese females.[1)]

Variable[2)]		Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	–.15	–.87	.05	–.24	–.03	.27
8	Cranial breadth	–.22	.79	–.17	–.17	–.01	.41
17	Basi-bregmatic height	.06	–.07	–.16	.05	–.05	.93***
3	Arc	.37	–.09	–.78**	.20	–.01	.20
4	Chord	–.16	–.70	–.55	–.04	.26	.17
1	Max. ht. about middle	–.59	–.16	.34	–.38	.26	–.09
K-4	Max. ht. at ant. end	–.06	–.25	–.02	.13	.82***	–.17
KKb-3C	Ht. at cost. angle	–.03	.06	–.08	.93***	–.06	.04
KKb-3D	Height at neck	.44	.02	.56	.46	.26	–.11
2	Thick. at mid. of body	.00	–.09	.78***	–.02	.14	–.03
KKb-4B	Thick. at ant. end	–.08	.22	.28	–.26	.75	.14
KKb-4C	Thick. at co. angle	–.89	–.17	–.00	–.01	–.04	.10
KKb-4D	Thickness at neck	–.80*	.16	.04	.07	.11	–.11

[1)] The sample size is 19. The cumulative proportion of the variances of the six principal components is 81.89%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-ailed bootstrap test.

Table 14. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the second rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.08	.18	.89*	.22	–.09	89.24
8	Cranial breadth	–.26	–.34	–.68	.49	–.14	90.35
17	Basi-bregmatic height	–.53	–.31	.27	.53	–.40	89.32
KKb-5A	Circumf. mid. body	.58	.53	–.05	.07	–.32	73.22
KKb-5B	Circumf. ant. end	.27	.53	–.19	.52	.49	90.27
KKb-5C	Circumf. cost. angle	.54	–.65	.25	.20	.29	89.64
KKb-5D	Circumf. of neck	.73	–.58	.08	.09	.09	89.37
K-6	Length of neck	–.72	.20	.22	.29	.31	79.54
KKb-7	Subtense	–.70	–.28	.08	–.35	.25	76.37
Total contribution (%)		29.01	18.77	16.60	12.21	8.66	85.26
Cumulative proportion (%)		29.01	47.78	64.38	76.60	85.26	85.26

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 15. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the second rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.08	.10	.86	.37	.08
8	Cranial breadth	.02	–.04	–.85	.41	.11
17	Basi-bregmatic height	–.06	–.18	–.01	.92*	–.13
KKb-5A	Circumf. mid. body	–.09	.81***	.14	–.17	.12
KKb-5B	Circumf. ant. end	–.02	.25	–.03	–.13	.91*
KKb-5C	Circumf. cost. angle	.94	–.05	.09	.03	.05
KKb-5D	Circumf. of neck	.91	.22	–.03	–.10	–.09
K-6	Length of neck	–.42	–.55	.16	.36	.39
KKb-7	Subtense	–.22	–.81**	–.02	.00	–.24

[1)] The sample size is 19. The cumulative proportion of the variances of the five principal components is 85.26%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 16. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the third rib from Japanese females.[1)]

Variable[2)]		Factor loadings						Total variance (%)
		PC I	II	III	IV	V	VI	
1	Cranial length	.72	−.18	−.28	−.07	−.07	−.38	78.73
8	Cranial breadth	−.53	−.03	.76*	.08	.11	−.11	88.50
17	Basi-bregmatic height	.01	−.28	.69	−.30	−.02	−.24	70.90
3	Arc	.24	−.77	.07	−.15	−.02	.40*	83.55
4	Chord	.72	−.45	.12	.04	−.36	.08	87.62
1	Max. ht. about middle	.44	−.01	.15	.14	.76*	.18	85.43
K-4	Max. ht. at ant. end	.67	.12	.27	−.14	.01	.55*	85.70
KKb-3C	Ht. at cost. angle	.30	.29	−.15	−.74*	.00	−.35	85.63
KKb-3D	Height at neck	.42	.42	−.12	.51	.34	−.11	75.29
2	Thick. at mid. of body	.14	.82	.09	−.30	−.20	.29	91.36
KKb-4B	Thick. at ant. end	.26	.01	.15	.63	−.50	−.19	77.25
KKb-4C	Thick. at co. angle	.51	.01	.34	−.04	.22	−.47	65.45
KKb-4D	Thickness at neck	.26	.62	.41	.11	−.26	.08	71.32
Total contribution (%)		20.79	17.28	12.32	11.26	9.63	9.23	80.52
Cumulative proportion (%)		20.79	38.07	50.39	61.65	71.28	80.52	80.52

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 17. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the first set of measurements of the neurocranium and the third rib from Japanese females.[1)]

Variable[2)]		Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	.25	−.13	−.21	.22	.14	−.77***
8	Cranial breadth	−.24	−.02	.80*	.03	−.02	.44
17	Basi-bregmatic height	.19	−.01	.80*	−.04	−.08	−.15
3	Arc	.83	−.35	.07	−.12	−.04	.07
4	Chord	.76	−.01	.01	.40	.01	−.37
1	Max. ht. about middle	.19	−.03	.04	−.18	.88***	−.02
K-4	Max. ht. at ant. end	.64	.56	−.03	−.04	.35	−.07
KKb-3C	Ht. at cost. angle	−.12	.29	.01	−.44	−.15	−.74***
KKb-3D	Height at neck	−.25	.17	−.29	.32	.68*	−.13
2	Thick. at mid. of body	−.14	.92*	−.15	−.17	−.06	−.03
KKb-4B	Thick. at ant. end	.04	.07	−.01	.87***	−.03	−.03
KKb-4C	Thick. at co. angle	.01	.04	.39	.16	.40	−.56
KKb-4D	Thickness at neck	−.09	.76	.14	.32	.10	−.01

[1)] The sample size is 20. The cumulative proportion of the variances of the six principal components is 80.52%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 18. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the third rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.54	.30	−.54	−.23	−.12	74.74
8	Cranial breadth	−.19	.03	.91**	.15	.07	89.07
17	Basi-bregmatic height	.18	.53	.59	−.15	−.02	68.10
KKb-5A	Circumf. mid. body	−.05	.57	−.15	.69	−.03	82.57
KKb-5B	Circumf. ant. end	.34	.39	−.28	.14	.73*	89.73
KKb-5C	Circumf. cost. angle	.74	.28	.13	.05	−.31	74.33
KKb-5D	Circumf. of neck	.34	−.32	.02	.76	−.22	84.11
K-6	Length of neck	−.46	.75	.10	.01	.09	79.14
KKb-7	Subtense	−.47	.53	−.28	−.09	−.50	82.60
KKb-8	Costal angle	.78	.18	.34	−.21	−.07	80.52
Total contribution (%)		21.90	18.92	17.90	12.22	9.56	80.49
Cumulative proportion (%)		21.90	40.81	58.71	70.94	80.49	80.49

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 19. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the third rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.41	.07	−.74	−.06	.17
8	Cranial breadth	.16	.03	.93*	−.00	−.09
17	Basi-bregmatic height	.60	.28	.43	−.21	.08
KKb-5A	Circumf. mid. body	.01	.65	−.00	.54	.32
KKb-5B	Circumf. ant. end	.10	.04	−.19	−.01	.92
KKb-5C	Circumf. cost. angle	.81	−.01	−.17	.25	.00
KKb-5D	Circumf. of neck	.07	−.21	.03	.89*	−.05
K-6	Length of neck	−.05	.79	.23	−.26	.21
KKb-7	Subtense	−.11	.78	−.24	−.15	−.35
KKb-8	Costal angle	.86	−.24	.01	−.04	.10

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 80.49%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 20. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the fourth rib from Japanese females.[1)]

Variable[2)]		Factor loadings						Total variance (%)
		PC I	II	III	IV	V	VI	
1	Cranial length	.77*	.23	−.32	−.30	−.07	.06	84.71
8	Cranial breadth	−.58	.25	.54	.17	−.31	−.01	82.26
17	Basi-bregmatic height	.12	.68	.57	.17	−.11	.24	89.52
3	Arc	.71*	.35	.27	.03	.17	−.38	87.85
4	Chord	.69**	.21	.38	−.18	.28	−.28	84.65
1	Max. ht. about middle	.57	.14	−.46	.40	−.35	−.01	83.52
K-4	Max. ht. at ant. end	.60	−.41	.08	−.16	−.17	−.31	68.30
KKb-3C	Ht. at cost. angle	−.19	.03	−.05	.62	.66	−.22	90.21
KKb-3D	Height at neck	−.34	−.64	.22	.32	−.22	−.33	82.92
2	Thick. at mid. of body	.13	−.58	.22	−.28	.44	.25	73.91
KKb-4B	Thick. at ant. end	.47	−.46	.53	−.06	−.21	.19	78.92
KKb-4C	Thick. at co. angle	.66**	−.26	.02	.47	−.28	.03	80.15
KKb-4D	Thickness at neck	.61	−.16	.05	.43	.26	.47*	86.50
Total contribution (%)		29.13	15.20	11.78	10.31	9.56	6.59	82.57
Cumulative proportion (%)		29.13	44.33	56.11	66.43	75.98	82.57	82.57

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.
[2)] See the second footnote to Table 2.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 21. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the first set of measurements of the neurocranium and the fourth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	.41	.11	−.61	.31	−.34	−.27
8	Cranial breadth	−.19	.16	.42	−.30	−.04	.70**
17	Basi-bregmatic height	.25	.09	−.22	.08	−.02	.88***
3	Arc	.89	.10	−.17	.21	.06	.10
4	Chord	.87	−.18	−.21	.08	−.02	.07
1	Max. ht. about middle	.09	.49	−.20	.71	−.08	−.18
K-4	Max. ht. at ant. end	.50	−.15	.21	.29	−.37	−.39
KKb-3C	Ht. at cost. angle	.04	−.00	.14	.04	.94***	−.02
KKb-3D	Height at neck	−.16	−.07	.88***	.05	.03	−.13
2	Thick. at mid. of body	.03	−.82***	.03	−.03	−.00	−.24
KKb-4B	Thick. at ant. end	.27	−.53	.26	.40	−.44	.12
KKb-4C	Thick. at co. angle	.24	.01	.16	.84*	−.11	−.07
KKb-4D	Thickness at neck	.10	−.40	−.25	.76**	.23	.06

[1)] The sample size is 20. The cumulative proportion of the variances of the six principal components is 82.57%.
[2)] See the second footnote to Table 2.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 22. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the fourth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	–.77	–.30	–.05	–.45	.02	88.93
8	Cranial breadth	.50	.30	.67	.21	–.05	83.23
17	Basi-bregmatic height	–.02	–.00	.86*	–.14	.20	80.55
KKb-5A	Circumf. mid. body	–.51	–.62	.21	.09	–.10	71.36
KKb-5B	Circumf. ant. end	–.68	.25	–.04	.24	–.51	83.79
KKb-5C	Circumf. cost. angle	–.16	–.70	.08	.52	.22	83.80
KKb-5D	Circumf. of neck	.47	–.66	–.12	.37	–.15	83.70
K-6	Length of neck	–.64	.24	.46	.27	–.18	78.45
KKb-7	Subtense	–.67	.20	–.10	.18	.53	80.91
KKb-8	Costal angle	.07	–.58	.30	–.52	–.13	72.67
Total contribution (%)		26.74	19.98	15.75	11.14	7.12	80.74
Cumulative proportion (%)		26.74	46.73	62.48	73.62	80.74	80.74

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 23. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the fourth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	–.23	–.85*	–.13	–.02	.30
8	Cranial breadth	.01	.51	.71	–.07	–.27
17	Basi-bregmatic height	–.01	–.16	.88	.01	.05
KKb-5A	Circumf. mid. body	–.30	–.55	.08	.56*	.03
KKb-5B	Circumf. ant. end	–.88*	–.08	–.21	–.07	.10
KKb-5C	Circumf. cost. angle	.01	–.10	.02	.90***	.13
KKb-5D	Circumf. of neck	.27	.15	–.16	.69*	–.49
K-6	Length of neck	–.76	–.07	.34	.04	.28
KKb-7	Subtense	–.20	–.09	–.06	.05	.87*
KKb-8	Costal angle	.24	–.65**	.26	.12	–.42

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 80.74%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 24. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the fifth rib from Japanese females.[1)]

Variable[2)]		Factor loadings						Total variance
		PC I	II	III	IV	V	VI	(%)
1	Cranial length	.74	.09	–.30	–.39	–.05	.05	79.57
8	Cranial breadth	–.58	.34	.18	.32	.40	.43*	93.10
17	Basi-bregmatic height	–.08	.91	–.04	.02	.18	.13	87.68
3	Arc	.60	.21	–.09	.57	–.18	–.04	77.46
4	Chord	.72	.46	.05	.21	–.25	–.08	84.72
1	Max. ht. about middle	.08	.76	.37	–.26	–.27	.09	87.19
K-4	Max. ht. at ant. end	.63	–.11	–.06	.41	–.10	.02	58.76
KKb-3C	Ht. at cost. angle	–.17	–.19	.82*	.21	.26	–.18	89.14
KKb-3D	Height at neck	.06	–.17	.73	–.12	–.58	.07	91.73
2	Thick. at mid. of body	.74	–.37	.02	.08	.17	.38	86.59
KKb-4B	Thick. at ant. end	.73	–.01	.28	.25	.34	–.07	79.54
KKb-4C	Thick. at co. angle	.59	–.16	.24	–.44	.17	.45	85.36
KKb-4D	Thickness at neck	.52	.21	.17	–.37	.49	–.46	92.40
Total contribution (%)		30.13	15.80	12.63	10.13	9.11	6.30	84.10
Cumulative proportion (%)		30.13	45.93	58.56	68.69	77.80	84.10	84.10

[1)] The sample size is 18. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 25. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the first set of measurements of the neurocranium and the fifth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	.25	.08	–.64	–.33	.03	.45
8	Cranial breadth	–.23	.42	.64*	.40	.37	–.04
17	Basi-bregmatic height	.04	.87	.03	–.04	.31	–.12
3	Arc	.87	.08	–.09	.02	.04	–.01
4	Chord	.75	.37	–.25	–.22	–.16	.09
1	Max. ht. about middle	.01	.84	–.08	–.11	–.38	–.00
K-4	Max. ht. at ant. end	.71	–.19	–.09	–.02	–.00	.20
KKb-3C	Ht. at cost. angle	–.04	–.10	.84	–.24	–.35	–.01
KKb-3D	Height at neck	.01	.02	.16	.10	–.93***	.11
2	Thick. at mid. of body	.45	–.29	–.06	–.04	.04	.76**
KKb-4B	Thick. at ant. end	.61	–.05	.23	–.45	.03	.40
KKb-4C	Thick. at co. angle	.01	.04	–.12	–.20	–.17	.88***
KKb-4D	Thickness at neck	.08	.14	–.03	–.92***	.09	.20

[1)] The sample size is 18. The cumulative proportion of the variances of the six principal components is 84.10%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 26. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the fifth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.66	.56	.26	−.11	.19	86.66
8	Cranial breadth	−.27	−.79	.36	.02	−.20	87.00
17	Basi-bregmatic height	.05	−.39	.78*	.06	.05	77.05
KKb-5A	Circumf. mid. body	−.42	.31	.50	−.04	.57	85.17
KKb-5B	Circumf. ant. end	.27	.31	.01	.60	−.46	74.06
KKb-5C	Circumf. cost. angle	−.58	.27	.18	.65	.13	87.34
KKb-5D	Circumf. of neck	−.41	.56	.36	.09	−.36	74.29
K-6	Length of neck	.66	−.51	.28	.32	.02	86.74
KKb-7	Subtense	.68	.01	−.14	.44	.36	79.70
KKb-8	Costal angle	.51	.37	.50	−.38	−.28	87.57
Total contribution (%)		24.17	20.63	15.59	12.48	9.69	82.56
Cumulative proportion (%)		24.17	44.80	60.39	72.87	82.56	82.56

[1)] The sample size is 18. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 27. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the fifth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.35	.82	−.22	.15	−.07
8	Cranial breadth	−.16	−.36	.82**	−.14	.13
17	Basi-bregmatic height	.07	.18	.83	.23	.02
KKb-5A	Circumf. mid. body	−.14	.10	.06	.88***	.19
KKb-5B	Circumf. ant. end	.15	.12	−.07	−.14	−.82
KKb-5C	Circumf. cost. angle	−.11	−.41	−.01	.66*	−.51*
KKb-5D	Circumf. of neck	−.59	.20	−.04	.35	−.49
K-6	Length of neck	.67	.14	.56	−.26	−.11
KKb-7	Subtense	.86*	.12	−.13	−.02	−.15
KKb-8	Costal angle	−.11	.91	.13	−.11	−.08

[1)] The sample size is 18. The cumulative proportion of the variances of the five principal components is 82.56%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 28. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the sixth rib from Japanese females.[1)]

Variable[2)]		Factor loadings						Total variance (%)
		PC I	II	III	IV	V	VI	
1	Cranial length	.68**	−.07	.18	.21	−.46	−.25	82.27
8	Cranial breadth	−.64**	.30	.10	−.56	−.06	.34	93.98
17	Basi-bregmatic height	−.15	.50	.63	.00	−.43	.30	95.34
3	Arc	.36	−.45	.51	.05	.44	.34	90.40
4	Chord	.66**	−.22	.63	−.08	−.04	−.03	88.49
1	Max. ht. about middle	.53*	.27	−.14	.66*	−.23	.27	93.18
K-4	Max. ht. at ant. end	.83***	.09	.26	−.05	.33	−.09	88.60
KKb-3C	Ht. at cost. angle	.21	.78	−.07	.14	.41	.13	87.21
KKb-3D	Height at neck	.54	−.24	−.47	.17	.08	.45	81.60
2	Thick. at mid. of body	.59*	−.33	−.21	−.47	−.23	.17	80.66
KKb-4B	Thick. at ant. end	.71***	.38	−.06	−.31	.18	−.19	81.62
KKb-4C	Thick. at co. angle	.69**	.05	−.26	−.34	−.23	.19	75.79
KKb-4D	Thickness at neck	.70*	.38	−.12	−.22	−.04	−.16	72.72
Total contribution (%)		35.32	13.46	11.92	10.23	8.28	6.32	85.53
Cumulative proportion (%)		35.32	48.78	60.70	70.94	79.21	85.53	85.53

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 29. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the first set of measurements of the neurocranium and the sixth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	.39	.16	.12	.75**	−.26	.05
8	Cranial breadth	−.11	.43	−.23	−.82**	−.02	−.11
17	Basi-bregmatic height	−.04	.95***	.04	−.01	.12	−.17
3	Arc	−.08	−.05	.93***	−.00	−.02	.16
4	Chord	.37	.21	.72**	.34	−.24	−.07
1	Max. ht. about middle	.06	.22	−.04	.69**	.38	.50*
K-4	Max. ht. at ant. end	.63	−.10	.58	.29	.21	.04
KKb-3C	Ht. at cost. angle	.33	.10	−.04	−.04	.86***	.04
KKb-3D	Height at neck	.13	−.27	.13	.19	.05	.82**
2	Thick. at mid. of body	.53	−.09	.15	−.02	−.51*	.48
KKb-4B	Thick. at ant. end	.86	−.08	.13	.09	.22	.03
KKb-4C	Thick. at co. angle	.67	.05	.01	.09	−.18	.51
KKb-4D	Thickness at neck	.81*	.01	−.02	.22	.14	.11

[1)] The sample size is 19. The cumulative proportion of the variances of the six principal components is 85.53%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 30. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the sixth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.70*	.35	.47	−.13	−.18	88.00
8	Cranial breadth	−.73	.41	−.25	.18	.30	89.21
17	Basi-bregmatic height	−.11	.79	−.15	.41	−.15	84.11
KKb-5A	Circumf. mid. body	.67	.01	−.06	.63	−.28	93.76
KKb-5B	Circumf. ant. end	.68*	.03	.17	−.24	.54	84.40
KKb-5C	Circumf. cost. angle	.61	.05	−.38	.29	.50	86.03
KKb-5D	Circumf. of neck	.81**	−.21	−.26	.20	−.03	80.23
K-6	Length of neck	−.22	.45	.71	.27	.26	89.32
KKb-7	Subtense	−.06	−.49	.71	.34	.05	85.53
KKb-8	Costal angle	.54	.59	.06	−.47	−.14	89.23
Total contribution (%)		33.31	17.44	15.59	12.07	8.56	86.98
Cumulative proportion (%)		33.31	50.75	66.35	78.42	86.98	86.98

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 31. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the sixth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.84	−.05	.25	.32	.11
8	Cranial breadth	−.43	.67	.00	−.51	−.02
17	Basi-bregmatic height	.14	.89*	.01	.13	−.09
KKb-5A	Circumf. mid. body	.11	.13	.07	.94***	.14
KKb-5B	Circumf. ant. end	.45	−.28	.11	.03	.74
KKb-5C	Circumf. cost. angle	−.03	.11	−.16	.39	.82
KKb-5D	Circumf. of neck	.15	−.22	−.24	.70*	.42
K-6	Length of neck	.18	.38	.82	−.23	.01
KKb-7	Subtense	−.21	−.40	.78*	.16	−.13
KKb-8	Costal angle	.90	.13	−.23	−.01	.13

[1)] The sample size is 19. The cumulative proportion of the variances of the five principal components is 86.98%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 32. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the seventh rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.63*	.07	.48	.22	–.08	68.46
8	Cranial breadth	–.42	–.36	–.72	.24	–.02	87.83
17	Basi-bregmatic height	.07	–.19	–.34	.84	.20	89.59
3	Arc	.51	–.53	.25	–.04	.52	86.81
4	Chord	.74*	–.26	.38	.14	.15	79.94
1	Max. ht. about middle	.03	.82	.29	.40	–.05	92.63
K-4	Max. ht. at ant. end	.80***	.16	–.11	–.22	–.19	76.27
KKb-3C	Ht. at cost. angle	–.20	.82	–.16	.13	.33	85.97
KKb-3D	Height at neck	–.45	.42	–.09	–.47	.46	82.44
2	Thick. at mid. of body	.73*	–.31	–.43	–.19	.08	85.65
KKb-4B	Thick. at ant. end	.70***	.15	–.42	–.15	–.02	71.72
KKb-4C	Thick. at co. angle	.77**	.38	–.20	.08	.20	82.07
KKb-4D	Thickness at neck	.63*	.50	–.35	–.05	–.18	79.69
Total contribution (%)		32.96	19.82	13.19	10.33	5.94	82.24
Cumulative proportion (%)		32.96	52.78	65.97	76.30	82.24	82.24

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 33. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the first set of measurements of the neurocranium and the seventh rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.23	–.21	.74	.06	.18
8	Cranial breadth	–.10	–.11	–.79	.46	–.13
17	Basi-bregmatic height	.01	–.03	–.06	.94	.08
3	Arc	.08	–.16	.18	.06	.89**
4	Chord	.27	–.30	.55	.11	.57
1	Max. ht. about middle	.04	.48	.65	.18	–.49*
K-4	Max. ht. at ant. end	.79	–.19	.27	–.17	.08
KKb-3C	Ht. at cost. angle	.09	.84	.09	.13	–.34
KKb-3D	Height at neck	–.15	.75**	–.29	–.40	–.01
2	Thick. at mid. of body	.73	–.28	–.18	.06	.45
KKb-4B	Thick. at ant. end	.84	–.03	–.00	.02	.11
KKb-4C	Thick. at co. angle	.78	.23	.33	.17	.16
KKb-4D	Thickness at neck	.84	.11	.19	.02	–.23

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 82.24%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 34. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the seventh rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.75	−.40	−.04	.06	−.33	82.99
8	Cranial breadth	−.75	−.18	.44	−.11	.31	90.27
17	Basi-bregmatic height	−.09	−.25	.66	−.45	−.09	71.22
KKb-5A	Circumf. mid. body	.78	.24	.40	−.15	−.15	87.21
KKb-5B	Circumf. ant. end	.67	−.11	.07	.29	.62	94.17
KKb-5C	Circumf. cost. angle	.45	.61	.52	−.18	−.01	87.97
KKb-5D	Circumf. of neck	.29	.72	−.25	−.15	.28	75.88
K-6	Length of neck	.17	−.46	.61	.49	.08	86.64
KKb-7	Subtense	−.13	.37	.08	.76	−.22	78.07
KKb-8	Costal angle	.51	−.64	−.39	−.21	.09	87.97
Total contribution (%)		27.88	19.70	16.65	12.36	7.66	84.24
Cumulative proportion (%)		27.88	47.58	64.22	76.58	84.24	84.24

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 35. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the seventh rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.84	.15	.26	−.12	.15
8	Cranial breadth	−.83	−.18	.39	−.16	−.09
17	Basi-bregmatic height	−.24	.37	.52	−.44	−.22
KKb-5A	Circumf. mid. body	.42	.82	.04	−.05	.17
KKb-5B	Circumf. ant. end	.23	.17	.01	−.04	.93*
KKb-5C	Circumf. cost. angle	−.04	.92	−.14	.08	.08
KKb-5D	Circumf. of neck	−.05	.37	−.76**	.07	.20
K-6	Length of neck	.04	.09	.81	.20	.41
KKb-7	Subtense	−.05	.01	.05	.88	−.00
KKb-8	Costal angle	.63	−.30	.05	−.55	.29

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 84.24%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Tabl 36. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the eighth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.63	.31	.36	–.34	.07	73.90
8	Cranial breadth	–.36	–.65	.19	.50	–.15	86.78
17	Basi-bregmatic height	.06	–.33	.58	.51	.47	92.46
3	Arc	.65	–.28	.21	–.37	.16	70.62
4	Chord	.72*	.22	.45	–.06	–.30	85.04
1	Max. ht. about middle	.49	.70	–.04	.32	–.11	85.16
K-4	Max. ht. at ant. end	.79**	–.13	–.20	.22	–.18	76.42
KKb-3C	Ht. at cost. angle	.06	.90	.04	.21	.08	87.38
KKb-3D	Height at neck	–.67	.44	–.25	.17	–.05	73.19
2	Thick. at mid. of body	.55	–.59	–.50	–.16	.04	92.50
KKb-4B	Thick. at ant. end	.70*	–.17	–.22	.39	–.38	85.75
KKb-4C	Thick. at co. angle	.74**	–.06	.04	.21	.12	60.80
KKb-4D	Thickness at neck	.49	.19	–.49	.16	.60	89.39
Total contribution (%)		33.45	20.70	10.73	9.47	7.14	81.49
Cumulative proportion (%)		33.45	54.15	64.88	74.35	81.49	81.49

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 37. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the first set of measurements of the neurocranium and the eighth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.80**	.30	–.07	–.08	.07
8	Cranial breadth	–.43	–.43	–.14	.58	–.38
17	Basi-bregmatic height	.12	–.04	.03	.95*	.05
3	Arc	.75	–.29	–.19	.03	.17
4	Chord	.71*	.34	–.42	.01	–.23
1	Max. ht. about middle	.14	.80	–.40	–.10	.16
K-4	Max. ht. at ant. end	.29	–.00	–.80***	–.02	.21
KKb-3C	Ht. at cost. angle	–.01	.91	.09	–.10	.15
KKb-3D	Height at neck	–.66	.35	.36	–.19	–.06
2	Thick. at mid. of body	.18	–.63	–.53	–.19	.41
KKb-4B	Thick. at ant. end	.10	.01	–.92***	–.00	.03
KKb-4C	Thick. at co. angle	.41	.09	–.54*	.21	.30
KKb-4D	Thickness at neck	.06	.16	–.24	.00	.90*

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 81.49%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 38. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the eighth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.75*	−.30	−.17	.04	−.42	86.27
8	Cranial breadth	−.68	−.40	.34	−.21	.30	88.00
17	Basi-bregmatic height	−.17	−.48	.64	−.01	−.36	80.16
KKb-5A	Circumf. mid. body	.84**	−.07	.33	.12	.12	85.40
KKb-5B	Circumf. ant. end	.54	−.53	−.10	.07	.53	86.74
KKb-5C	Circumf. cost. angle	.61	.43	.54	.07	−.09	85.90
KKb-5D	Circumf. of neck	.20	.62	.31	.38	.30	74.75
K-6	Length of neck	.03	−.79	.24	.32	.05	78.41
KKb-7	Subtense	−.27	−.14	−.32	.83	−.10	90.36
KKb-8	Costal angle	.73*	−.26	−.33	−.29	.06	80.04
Total contribution (%)		30.94	20.46	13.21	10.93	8.07	83.60
Cumulative proportion (%)		30.94	51.40	64.61	75.54	83.60	83.60

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 39. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the eighth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.89*	−.15	.01	−.01	.24
8	Cranial breadth	−.75*	−.43	−.34	−.12	.08
17	Basi-bregmatic height	−.05	−.88*	−.02	−.08	−.10
KKb-5A	Circumf. mid. body	.46	−.15	.60*	−.17	.49
KKb-5B	Circumf. ant. end	.16	−.01	.01	−.00	.92***
KKb-5C	Circumf. cost. angle	.30	−.08	.83***	−.28	−.05
KKb-5D	Circumf. of neck	−.18	.26	.79***	.12	−.04
K-6	Length of neck	.01	−.65	−.14	.30	.49
KKb-7	Subtense	−.02	−.00	−.09	.95	−.03
KKb-8	Costal angle	.62	.19	−.11	−.30	.53*

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 83.60%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 40. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the ninth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.61	.02	.28	.69	−.04	92.25
8	Cranial breadth	−.43	.54	−.46	−.25	−.07	75.65
17	Basi-bregmatic height	−.11	.47	−.53	.38	.50	90.02
3	Arc	.63	.51	.37	−.04	.33	90.87
4	Chord	.66	.44	.14	.32	−.03	75.75
1	Max. ht. about middle	.57	−.61	−.15	.22	−.06	76.89
K-4	Max. ht. at ant. end	.84***	−.16	−.24	−.24	−.04	84.94
KKb-3C	Ht. at cost. angle	.49	−.64	−.43	−.09	−.11	85.44
KKb-3D	Height at neck	−.11	−.61	.02	.24	.11	45.39
2	Thick. at mid. of body	.54	.18	.42	−.55	.21	85.40
KKb-4B	Thick. at ant. end	.75*	.26	−.22	−.28	−.40	92.57
KKb-4C	Thick. at co. angle	.40	.53	−.52	.20	−.18	78.52
KKb-4D	Thickness at neck	.38	−.33	−.31	−.22	.68	86.58
Total contribution (%)		29.63	20.22	12.34	10.93	8.44	81.56
Cumulative proportion (%)		29.63	49.85	62.19	73.12	81.56	81.56

[1)] The sample size is 18. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 41. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the first set of measurements of the neurocranium and the ninth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.04	−.14	−.06	.95***	.01
8	Cranial breadth	−.15	.39	−.41	−.55	.34
17	Basi-bregmatic height	−.11	.14	−.14	.03	.92***
3	Arc	.79	.11	−.22	.45	.15
4	Chord	.32	.01	−.44	.67*	.13
1	Max. ht. about middle	−.10	−.78	.06	.36	−.13
K-4	Max. ht. at ant. end	.37	−.72*	−.41	.15	−.07
KKb-3C	Ht. at cost. angle	−.13	−.90	−.08	−.03	−.12
KKb-3D	Height at neck	−.29	−.32	.51*	.09	−.06
2	Thick. at mid. of body	.88	−.08	−.11	.02	−.23
KKb-4B	Thick. at ant. end	.30	−.35	−.81*	.12	−.20
KKb-4C	Thick. at co. angle	−.07	−.07	−.76	.21	.39
KKb-4D	Thickness at neck	.40	−.66	.25	−.15	.43

[1)] The sample size is 18. The cumulative proportion of the variances of the five principal components is 81.56%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 42. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the ninth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.57	.24	.46	.23	.53	92.15
8	Cranial breadth	–.68	.32	–.41	.12	–.31	84.11
17	Basi-bregmatic height	–.32	.44	–.36	.49	.46	87.40
KKb-5A	Circumf. mid. body	.88***	.04	–.12	.16	–.05	81.33
KKb-5B	Circumf. ant. end	.74**	.36	–.08	.01	–.37	81.85
KKb-5C	Circumf. cost. angle	.68**	.31	–.57	.06	–.04	88.79
KKb-5D	Circumf. of neck	.47	–.66	–.37	.31	.08	89.40
K-6	Length of neck	–.18	.74	.33	.34	–.23	85.22
KKb-7	Subtense	.02	–.46	.33	.69	–.40	94.44
KKb-8	Costal angle	.66**	.26	.19	–.27	–.14	62.74
Total contribution (%)		33.60	18.27	12.38	10.87	9.63	84.74
Cumulative proportion (%)		33.60	51.87	64.24	75.11	84.74	84.74

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 43. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the second set of measurements of the neurocranium and the ninth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.21	.12	.92***	.01	.14
8	Cranial breadth	–.14	.33	–.76*	–.04	.37
17	Basi-bregmatic height	–.06	.15	–.02	–.10	.91**
KKb-5A	Circumf. mid. body	.78*	–.23	.37	.14	–.07
KKb-5B	Circumf. ant. end	.86*	.16	.12	.04	–.20
KKb-5C	Circumf. cost. angle	.88	–.20	.00	–.18	.21
KKb-5D	Circumf. of neck	.27	–.82	.10	.37	.07
K-6	Length of neck	.11	.87	.01	.16	.23
KKb-7	Subtense	–.08	–.04	.02	.96*	–.08
KKb-8	Costal angle	.56	.15	.34	–.17	–.39

[1)] The sample size is 19. The cumulative proportion of the variances of the five principal components is 84.74%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 44. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the tenth rib from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.55	−.52	.46	−.03	−.25	84.46
8	Cranial breadth	−.38	.70	.13	.40	−.11	82.10
17	Basi-bregmatic height	−.04	.47	.76	.04	.24	86.59
3	Arc	.66**	.18	.02	.53	−.36	88.52
4	Chord	.68*	−.16	.38	.30	−.18	75.34
1	Max. ht. about middle	.80**	−.27	−.20	−.37	−.07	88.59
K-4	Max. ht. at ant. end	.92***	.13	−.04	−.20	.08	91.13
KKb-3C	Ht. at cost. angle	.60*	.37	.09	−.28	−.36	71.04
KKb-3D	Height at neck	−.48	.52	.01	−.35	−.39	76.72
2	Thick. at mid. of body	.53	.23	−.67	.27	.10	87.48
KKb-4B	Thick. at ant. end	.53	.59	−.28	.09	.23	77.08
KKb-4C	Thick. at co. angle	.60	.21	.34	−.11	.52	80.68
KKb-4D	Thickness at neck	.14	.80	.01	−.30	−.12	75.74
Total contribution (%)		33.55	20.14	12.70	8.36	7.21	81.96
Cumulative proportion (%)		33.55	53.68	66.38	74.75	81.96	81.96

[1)] The sample size is 20. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 45. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the first set of measurements of the neurocranium and the tenth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	−.15	−.67	−.50	−.33	.12
8	Cranial breadth	.30	.00	.84***	.11	.07
17	Basi-bregmatic height	.23	−.12	.41	−.26	.75***
3	Arc	.09	−.82***	.07	.44	−.03
4	Chord	−.10	−.81***	−.19	.05	.23
1	Max. ht. about middle	.10	−.29	−.85**	.28	.03
K-4	Max. ht. at ant. end	.23	−.39	−.59*	.48	.37
KKb-3C	Ht. at cost. angle	.64	−.40	−.30	.20	.14
KKb-3D	Height at neck	.69*	.31	.32	−.23	−.19
2	Thick. at mid. of body	−.03	−.11	−.13	.91***	−.14
KKb-4B	Thick. at ant. end	.28	−.08	.00	.77***	.32
KKb-4C	Thick. at co. angle	.01	−.16	−.26	.25	.81***
KKb-4D	Thickness at neck	.77**	.08	.14	.27	.24

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 81.96%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 46. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the tenth rib from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.51	−.41	.22	.56	79.04
8	Cranial breadth	−.29	.85	−.19	−.09	84.88
17	Basi-bregmatic height	−.13	.49	.63	.55	96.22
KKb-5A	Circumf. mid. body	.88	−.14	.09	.01	80.23
KKb-5B	Circumf. ant. end	.76	.27	.17	−.33	78.83
KKb-5C	Circumf. cost. angle	.62	.58	.23	.22	82.65
KKb-5D	Circumf. of neck	−.39	.38	.67	−.19	78.84
K-6	Length of neck	.45	.71	−.43	−.15	92.26
KKb-7	Subtense	.06	.23	−.68	.59	86.55
KKb-8	Costal angle	.80	−.13	.09	−.22	71.46
Total contribution (%)		30.97	22.86	16.74	12.52	83.10
Cumulative proportion (%)		30.97	53.84	70.58	83.10	83.10

[1)] The sample size is 12. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 47. Solution obtained through the normal varimax rotation of the first four principal components for the correlation matrix on the second set of measurements of the neurocranium and the tenth rib from Japanese females.[1)]

Variable[2)]		Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.28	−.78	.22	.25
8	Cranial breadth	−.09	.85	.31	.14
17	Basi-bregmatic height	−.08	−.01	.98**	−.06
KKb-5A	Circumf. mid. body	.80	−.38	−.06	.11
KKb-5B	Circumf. ant. end	.87	.11	.02	−.13
KKb-5C	Circumf. cost. angle	.68	.13	.56	.19
KKb-5D	Circumf. of neck	−.17	.28	.52	−.64
K-6	Length of neck	.56	.65	.02	.42
KKb-7	Subtense	−.11	.12	.06	.91*
KKb-8	Costal angle	.79	−.24	−.19	−.05

[1)] The sample size is 12. The cumulative proportion of the variances of the four principal components is 83.10%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 48. Principal component analysis of the correlation matrix on the measurements of the neurocranium and the eleventh rib from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.59	.26	−.73	−.11	95.53
8	Cranial breadth	−.44	.51	.59	.09	81.02
17	Basi-bregmatic height	−.45	.64	−.15	−.47	85.25
3	Arc	.66	.72	.15	.02	97.30
4	Chord	.63	.64	−.09	−.17	84.51
1	Max. ht. about middle	.71	−.46	.40	−.33	98.14
2	Thick. at mid. of body	.66*	−.15	−.16	.56	79.51
KKb-5A	Circumf. mid. body	.74	−.47	.32	−.33	98.27
KKb-7	Subtense	.40	.62	.41	.25	77.36
Total contribution (%)		35.82	27.72	15.39	9.62	88.54
Cumulative proportion (%)		35.82	63.54	78.93	88.54	88.54

[1)] The sample size is 19. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 49. Solution obtained through the normal varimax rotation of the first four principal components for the correlation matrix on the measurements of the neurocranium and the eleventh rib from Japanese females.[1)]

Variable[2)]		Factor loadings			
		Fac I	II	III	IV
1	Cranial length	−.04	.35	−.91	.06
8	Cranial breadth	−.29	.31	.74	−.29
17	Basi-bregmatic height	−.39	.18	−.03	−.82
3	Arc	.10	.97*	−.14	.02
4	Chord	.11	.82	−.38	−.12
1	Max. ht. about middle	.97*	.09	−.04	.19
2	Thick. at mid. of body	.11	.25	−.30	.79
KKb-5A	Circumf. mid. body	.96*	.08	−.13	.20
KKb-7	Subtense	−.01	.83	.25	.14

[1)] The sample size is 19. The cumulative proportion of the variances of the four principal components is 88.54%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 50. Principal component analysis of the correlation matrix on the measurements of the neurocranium and the twelfth rib from Japanese females.[1)]

Variable[2)]		Factor loadings			Total variance (%)
		PC I	II	III	
1	Cranial length	.35	.78	−.21	77.45
8	Cranial breadth	.13	−.91	.10	85.87
17	Basi-bregmatic height	.55	−.40	−.15	48.91
3	Arc	.94***	−.12	−.12	91.78
4	Chord	.93***	−.10	−.09	88.72
1	Max. ht. about middle	.34	.40	.80	91.54
2	Thick. at mid. of body	−.17	−.38	.71	67.66
KKb-5A	Circumf. mid. body	.51	.16	.77*	88.78
KKb-7	Subtense	.87***	−.01	−.23	80.89
Total contribution (%)		37.33	21.71	21.14	80.18
Cumulative proportion (%)		37.33	59.04	80.18	80.18

[1)] The sample size is 17. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 51. Solution obtained through the normal varimax rotation of the first three principal components for the correlation matrix on the measurements of the neurocranium and the twelfth rib from Japanese females.[1)]

Variable[2)]		Factor loadings		
		Fac I	II	III
1	Cranial length	.20	.85	.12
8	Cranial breadth	.30	−.87	−.11
17	Basi-bregmatic height	.65	−.24	−.08
3	Arc	.94***	.07	.15
4	Chord	.92***	.07	.17
1	Max. ht. about middle	.03	.17	.94
2	Thick. at mid. of body	−.25	−.61	.50
KKb-5A	Circumf. mid. body	.25	−.02	.91
KKb-7	Subtense	.88***	.19	.05

[1)] The sample size is 17. The cumulative proportion of the variances of the three principal components is 80.18%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 52. Comparison of the principal components from all the former sets of measurements of the neurocranium and the second to the tenth rib.[1)]

Principal components compared (Rib No.)	Spearman's rank corr.	Principal components compared (Rib No.)	Spearman's rank corr.
II (2) – I (4)	0.79**	IV (5) – V (6)	0.70**
– III (8)	0.71**	V (5) – III (7)	0.76**
III (2) – III (3)	0.74**	I (6) – VI (6)	0.71**
V (2) – V (6)	0.84***	– I (7)	0.77**
I (3) – III (7)	0.76**	– I (8)	0.70**
– II (8)	0.69**	II (6) – IV (8)	0.72**
II (3) – II (4)	0.82***	– III (9)	0.77**
– II (5)	0.75**	III (6) – III (8)	0.75**
– III (6)	0.76**	IV (6) – III (7)	0.79**
– III (8)	0.88***	– II (8)	0.73**
III (3) – IV (8)	0.69**	VI (6) – V (7)	0.69**
– III (9)	0.69**	I (7) – I (8)	0.90***
I (4) – I (8)	0.71**	II (7) – II (8)	0.78**
II (4) – II (5)	0.77**	– II (9)	0.77**
– III (6)	0.73**	III (7) – IV (9)	0.74**
– IV (7)	0.82***	– II (10)	0.80***
– III (8)	0.86***	IV (7) – III (8)	0.75**
III (4) – II (7)	0.70**	I (8) – I (9)	0.81***
– II (8)	0.75**	– I (10)	0.75**
– IV (10)	0.70**	II (8) – II (9)	0.76**
IV (4) – I (5)	0.75**	– IV (10)	0.73**
– III (5)	0.69**	III (8) – III (10)	0.86***
I (5) – I (7)	0.71**	IV (8) – III (9)	0.77**
– I (8)	0.69**	I (9) – I (10)	0.74**
– I (9)	0.72**	II (9) – IV (10)	0.80***
– III (9)	0.69**	IV (9) – III (10)	0.73**
II (5) – IV (7)	0.73**	I (10) – II (10)	0.79**

[1)] The data used are of females. The similarity in the variation patterns of factor loadings between two PCs was assessed by using Spearman's rank correlation coefficient. The signs of rank correlations are removed because the signs of factor loadings are reversible. Only the PCs which show significantly similar loading variation patterns at the 1% level are listed.

** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 53. Comparison of the rotated factors for all the former sets of measurements of the neurocranium and the second to the tenth rib.[1)]

Rotated factors compared (Rib No.)	Spearman's rank corr.	Rotated factors compared (Rib No.)	Spearman's rank corr.
II (2) – III (5)	0.92***	IV (5) – I (6)	0.70**
– III (7)	0.75**	V (5) – II (8)	0.80**
– I (8)	0.83***	VI (5) – I (6)	0.81***
– IV (9)	0.80***	I (6) – I (7)	0.92***
– I (10)	0.83***	II (6) – IV (7)	0.92***
III (2) – IV (8)	0.73**	III (6) – V (7)	0.80***
VI (2) – II (3)	0.69**	IV (6) – III (7)	0.79**
– II (9)	0.76**	– IV (9)	0.70**
I (3) – I (4)	0.95***	V (6) – II (7)	0.69**
– I (5)	0.74**	– V (7)	0.76**
– I (8)	0.80***	I (7) – III (8)	0.78**
– IV (9)	0.76**	II (7) – V (7)	0.75**
– II (10)	0.80**	– I (10)	0.69**
II (3) – II (4)	0.82***	III (7) – I (8)	0.71**
III (3) – IV (7)	0.73**	– IV (9)	0.75**
– IV (8)	0.82***	– III (10)	0.77**
– V (9)	0.70**	V (7) – I (8)	0.75**
V (3) – IV (6)	0.70**	– I (10)	0.73**
I (4) – I (5)	0.81***	I (8) – IV (9)	0.82***
– I (8)	0.78**	– I (10)	0.90***
– IV (9)	0.73**	– II (10)	0.78**
– II (10)	0.71**	III (8) – IV (10)	0.73**
II (4) – I (6)	0.71**	IV (8) – II (9)	0.70**
VI (4) – IV (8)	0.70**	– V (9)	0.78**
– III (10)	0.73**	IV (9) – I (10)	0.75**
I (5) – III (6)	0.87***	– II (10)	0.71**
– V (7)	0.71**		
– I (9)	0.80***		
II (5) – II (6)	0.81***		
III (5) – III (7)	0.79**		
– I (8)	0.90***		
– IV (9)	0.82***		
– I (10)	0.81***		

[1)] The data used are of females. The similarity in the variation patterns of factor loadings between two rotated factors was assessed by using Spearman's rank correlation coefficient. The signs of rank correlations are removed because the signs of factor loadings are reversible. Only the rotated factors which show significantly similar loading variation patterns at the 1% level are listed.

** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 54. Comparison of the principal components from all the latter sets of measurements of the neurocranium and the third to the tenth rib.[1)]

Principal components compared (Rib No.)	Spearman's rank corr.	Principal components compared (Rib No.)	Spearman's rank corr.
III (3) – I (4)	0.84**	III (6) – III (9)	0.94***
V (3) – II (8)	0.82**	I (7) – I (8)	0.96***
II (4) – II (8)	0.82**	– I (9)	0.88***
III (4) – I (6)	0.77**	– I (10)	0.78**
– II (6)	0.83**	V (7) – V (8)	0.85**
IV (4) – IV (5)	0.81**	– IV (10)	0.87**
V (4) – IV (10)	0.89***	I (8) – I (9)	0.84**
I (5) – III (6)	0.88***	– I (10)	0.78**
– III (9)	0.88***	II (8) – II (9)	0.84**
II (5) – I (6)	0.92***	V (8) – IV (10)	0.81**
– III (7)	0.82**	I (9) – I (10)	0.83**
V (5) – V (7)	0.90***	V (9) – III (10)	0.78**
– IV (10)	0.84**		
II (6) – II (7)	0.81**		
– IV (8)	0.77**		

[1)] The data used are of females. The similarity in the variation patterns of factor loadings between two PCs was assessed by using Spearman's rank correlation coefficient. The signs of rank correlations are removed because the signs of factor loadings are reversible. Only the PCs which show significantly similar loading variation patterns at the 1% level are listed.

** $P<0.01$; *** $P<0.001$, by a two-tailed test.

the middle of the body, and costal angle (Table 38).

As for cranial breadth, there were no PCs which were significantly correlated with this breadth and any of costal measurements in the same direction.

The PCs which are significantly correlated with both basi-bregmatic height and some costal measurements are as follows: PC I for the first rib, which is correlated with the circumference at the middle of the body, the circumference at the anterior end, the length of the neck, and costal subtense (Table 10).

On the other hand, the rotated factors which are significantly correlated with both cranial length and some costal measurements are as follows: Fac VI for the third rib, which is correlated with the height at the costal angle (Table 17); Fac II for the fourth rib, which is correlated with costal angle (Table 23); Fac IV for the sixth rib, which is correlated with the maximum height about the middle (Table 29); Fac I for the eighth rib, which is correlated with costal chord (Table 37); and Fac IV for the ninth rib, which is correlated with costal chord (Table 41).

The rotated factor which was found to be significantly correlated with both cranial breadth and some costal measurements is only Fac III for the tenth rib. This factor is correlated with the maximum heights about the middle and at the anterior end

Table 55. Comparison of the rotated factors for all the latter sets of measurements of the neurocranium and the third to the tenth rib.[1)]

Rotated factors compared (Rib No.)	Spearman's rank corr.	Rotated factors compared (Rib No.)	Spearman's rank corr.
I (3) – IV (8)	0.78**	IV (5) – IV (6)	0.93***
– IV (9)	0.94***	– II (7)	0.78**
II (3) – III (6)	0.89***	– III (8)	0.82**
III (3) – III (5)	0.92***	– II (9)	0.88***
– II (6)	0.81**	IV (6) – III (8)	0.87**
IV (3) – I (5)	0.81**	– II (9)	0.93***
– III (7)	0.79**	V (6) – I (9)	0.93***
V (3) – I (10)	0.83**	I (7) – I (8)	0.95***
I (4) – III (6)	0.85**	– III (9)	0.88***
II (4) – I (8)	0.84**	II (7) – III (8)	0.84**
– II (10)	0.93***	III (7) – II (8)	0.78**
III (4) – III (5)	0.90***	– III (8)	0.82**
– II (6)	0.93***	V (7) – V (8)	0.79**
IV (4) – II (9)	0.77**	I (8) – III (9)	0.77**
V (4) – I (5)	0.92***	– II (10)	0.77**
– III (6)	0.83**	II (8) – V (9)	0.81**
– IV (10)	0.78**	III (8) – II (9)	0.77**
I (5) – III (6)	0.85**	IV (8) – IV (9)	0.84**
III (5) – II (6)	0.93***	V (8) – III (10)	0.90***

[1)] The data used are of females. The similarity in the variation patterns of factor loadings between two rotated factors was assessed by using Spearman's rank correlation coefficient. The signs of rank correlations are removed because the signs of factor loadings are reversible. Only the rotated factors which show significantly similar loading variation patterns at the 1% level are listed.

** $P<0.01$; *** $P<0.001$, by a two-tailed test.

(Table 45).

The rotated factors which are significantly correlated with both basi-bregmatic height and some costal measurements are as follows: Fac V for the first rib, which is correlated with costal arc (Table 9); and Fac V for the tenth rib, which is correlated with the thickness at the costal angle (Table 45).

From the above results, *i.e.*, PC I's for the fourth, sixth and seventh ribs as well as Fac I for the eighth and Fac IV for the ninth rib, it is inferable that costal chord is strongly associated with cranial length, and, from the same three PCs, that the thickness at the costal angle may also be associated with cranial length together with costal chord.

In Tables 52 to 55, Spearman's rank correlation coefficients between the variation patterns in factor loadings of the PCs or rotated factors for the second or third to the tenth rib are listed. From these rank correlations, the reality of some of the above-

Table 56. Principal component analysis of the correlation matrix on three cranial measurements and the costal chords of the first to the tenth rib from Japanese females.[1)]

Variable[2)]	Factor loadings			Total variance (%)
	PC I	II	III	
1 Cranial length	.70***	−.14	.06	50.63
8 Cranial breadth	−.37	.86	.13	90.12
17 Basi-bregmatic height	.22	.68	−.57	82.75
4 Chord of 1st rib	.83***	−.09	−.18	72.25
2nd rib	.91***	−.06	−.06	83.99
3rd rib	.97***	.08	−.02	94.10
4th rib	.91***	.10	−.26	90.28
5th rib	.91***	−.03	−.27	89.74
6th rib	.95***	−.14	−.18	95.18
7th rib	.96***	−.14	.01	94.14
8th rib	.91***	.10	.31	92.78
9th rib	.89***	.28	.33	97.14
10th rib	.78**	.24	.54	94.88
Total contribution (%)	67.67	11.06	8.03	86.77
Cumulative proportion (%)	67.67	78.73	86.77	86.77

[1)] The sample size is 15. The number of the principal components shown here was so determined that the cumulative proportion of the variances of the principal components exceeded 80%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

mentioned factors, *i.e.*, at least PC I's for the sixth and seventh ribs and Fac I for the eighth and Fac IV for the ninth rib can be confirmed (Tables 52 and 53).

As for the eleventh and twelfth ribs, only one significant rank correlation coefficient was obtained. But the factors in question were not significantly correlated with any of the cranial measurements.

Since a tight connection between cranial length and costal chord was suggested in the above analyses, the correlations between the three cranial measurements and the chords of all the ribs but the eleventh and twelfth were newly analyzed in the same way as the above. The reason why all the ribs were not used in this analysis is again the statistical limitation relating to the number of variables and sample size. In result, it was found that PC I was significantly correlated both with cranial length and with the chords of all the ribs analyzed at the 1% level (Table 56), and that Fac I had significant correlations with cranial length and the chords of only the first to seventh rib at the 5% level (Table 57).

Table 57. Solution obtained through the normal varimax rotation of the first three principal components for the correlation matrix on three cranial measurements and the costal chords of the first to the tenth rib from Japanese females.[1)]

Variable[2)]	Factor loadings		
	Fac I	II	III
1 Cranial length	.56*	−.12	.42
8 Cranial breadth	−.63**	.69	.17
17 Basi-bregmatic height	.26	.87	−.04
4 Chord of 1st rib	.78**	.04	.34
2nd rib	.78***	.02	.49
3rd rib	.76*	.13	.59
4th rib	.83*	.25	.39
5th rib	.87*	.14	.34
6th rib	.89***	.00	.40
7th rib	.81**	−.08	.53
8th rib	.53	−.02	.80*
9th rib	.45	.13	.87**
10th rib	.27	.00	.94*

[1)] The sample size is 15. The cumulative proportion of the variances of the three principal components is 86.77%.

[2)] See the second footnote to Table 2.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Discussion

No significant associations were found in the analyses on the sternum and the nuerocranium possibly because of the small sample size. In the following, therefore, only the results from the ribs and the neurocranium will be discussed.

It has widely been accepted that, compared with tetrapods, the position of the human vertebral column in the cross section of the thorax is close to the center of the cross section because of their bipedalism. And it has been asserted in general that the shape of the human head may be biomechanically related with the position of the vertebral column. As far as the present author knows, however, such a relationship has not been biomechanically or statistically confirmed until now. It was therefore expected that the present statistical analyses might show the reality of the relationship.

In result, the present analyses showed that cranial length was significantly associated with the chords of at least the first to the seventh rib (Tables 56 and 57), and also associated with the thiknesses at the angle of the ribs located about the middle of the thorax (Tables 20, 28 and 32). Although it is unclear how these findings are concerned with the above relationship between the head shape and the position of the vertebral column in the thorax cross section, there is no doubt that cranial length is

associated with the anteroposterior diameter of the thorax. And it is interesting that a rotated factor correlated with cranial length has significant correlations with the chords of the first to the seventh rib alone (Table 57) because only these ribs are tightly connected to the sternum in practice. This may only imply that the first seven ribs, or true ribs, are functionally different from the other ribs, or false ribs. Anyhow, it is unknown whether the association between the structures of the neurocranium and the thorax in the sagittal direction is biomechanically caused by the posture of the body or produced by the pleiotropic genes which were rigidly fixed in our ancestral population in considerably ancient times.

The positive correlations between costal chord and thicknesses suggested by the PC I's in Tables 20, 28 and 32 may be interpreted as a result of biomechanical coordination according to the lengthened state of the ribs.

Although, presumably, there have been no investigations on the relation between the skull and the ribs, Kouchi (1977) analyzed the somatometric data from 56 17-year-old Japanese boys using PCA and showed that, apart from the so-called general size factor (PC I), PC V which was most highly correlated with head length (factor loading=−0.46) had a correlation (*i.e.*, factor loading) of −0.23 with chest depth. Further, Mizoguchi (1992) carried out a PCA and a canonical correlation analysis on the somatometric data from about 100 Japanese males reported by Hoshi and Kouchi (1978). In his results, PC VII which was most highly correlated with head length had a correlation of 0.41 with the head length and a correlation of −0.33 with chest depth. On the other hand, the correlation coefficient between the second canonical variate and head length was 0.98, and that between the corresponding canonical variate and chest depth was 0.37. And the canonical correlation coefficient between these second canonical variates was as low as 0.58. In sum, the results based on the above two sets of somatometric data seem not to be consistent with those of the present study based on osteometric data, though one of the causes for the difference between them may be measurement errors, especially for chest depth.

For the relation in shape between the head and the thorax, there are few studies. It is desired that both statistical and biomechanical researches will more intensively be carried out for solving this problem in the future.

Summary and Conclusions

The materials used in the present multivariate analyses are only those of females because the male sample was too small.

In the analyses on the neurocranium and the sternum, no significant associations were found between them.

Regarding the relations between the neurocranium and the ribs, the present analyses showed that cranial length was significantly associated with the chords of at least the first to the seventh rib, and also with the thicknesses at the angle of the ribs

located about the middle of the thorax.

Although it is unknown whether the association between the neurocranium and the thorax is biomechanically caused or genetically produced, it is interesting that a rotated factor correlated with cranial length exclusively has significant correlations with only seven ribs, the first to the seventh, which are tightly connected to the sternum.

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