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Associations between the Neurocranium and the Foot Bones: Toward the Solution of the Brachycephalization Problem

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Abstract Aiming at clarifying the causes of brachycephalization in the end, the correlations between neurocranial and foot bone measurements were examined using principal component analysis and Kaiser's normal varimax rotation methods. The results show that, while neither cranial length nor breadth is consistently associated with any measurements of the foot bones, basi-bregmatic height is significantly associated with the size of the talus in both males and females and, only in females, also with the size of the other foot bones. Although it was tentatively suggested that a biomechanical factor relating to the balance in posture might be one of the causes for these associations, much more detailed analyses should be conducted in the future to solve this problem.
Key words : Neurocranium, Basi-bregmatic height, Foot bones, Talus, Posture

In 1992, the present author tried to find any strong associations between neurocranial and postcranial bone measurements using some limited number of measurements (Mizoguchi, 1992) because we may be able to determine the causes and mechanism of brachycephalization, though indirectly, if there are such strong associations. As a result, he found relatively strong associations between one or more neurocranial measurements and a few measurements of the third lumbar vertebra, pelvis, talus, etc. Since then, he has examined the associations between the three main neurocranial measurements, i.e., cranial length, cranial breadth and basi-bregamtic height, and the measurements thoroughly taken of each postcranial bone. Up to the present, this series of multivariate analyses have shown that cranial length is strongly associated with the sagittal and transverse diameters of the vertebral bodies, sacral breadths, costal chords, many humeral measurements, pelvic breadths and height, femoral lengths and thicknesses, and tibial lengths and thicknesses; that cranial breadth has no consistent association with any measurements of the vertebrae, ribs, sternum, scapula, clavicle, humerus, ulna, radius, pelvis, femur, patella, tibia or fibula; and that basi-bregmatic height is significantly associated with the transverse diameters of the vertebral foramina of almost all the vertebrae (Mizoguchi, 1992, 1994, 1995, 1996, 1997, 1998a, b, 1999, 2000, 2001, 2002, 2003a, b, c).

In the present study, i.e., the final analysis of this series, the correlations between neurocranial and foot bone measurements are examined similarly toward solving the brachycephalization problem.

Materials and Methods

The data used here are the raw measurements of the neurocranium reported by Miyamoto (1924) and those of the talus, the calcaneus, the navicular bone, the cuboid bone, the medial (first), intermediate (second) and lateral (third) cuneiform bones, the first, second, third, fourth and fifth metatarsal bones, the first, second, third, fourth and fifth proximal foot phalanges, the second, third, fourth and fifth middle foot phalanges, and the first, second, third, fourth and fifth distal foot phalanges reported by Hirai and Tabata (1928). These are of the same skeletons of 30 male and 20 female modern Japanese who had lived in the Kinai district. The basic statistics for three main neurocranial measurements, i.e., cranial length, cranial breadth and basi-bregmatic height, are presented in Mizoguchi (1994), and those for foot bone measurements are listed in Tables 1 to 7.

For examining the overall relations between the neurocranial and the foot bone measurements, principal component analysis (Lawley and Maxwell, 1963; Okuno *et al.*, 1971, 1976; Takeuchi and Yanai, 1972) was applied to the correlation matrices on them. The number of principal components was so determined that the cumulative proportion of the variances of the principal components exceeded 80%. The principal components obtained in such a way were then transformed by Kaiser's normal varimax rotation method (Asano, 1971; Okuno *et al.*, 1971) into different factors because these may reveal some other associations hidden behind the measurements dealt with.

The measurements of the talus and of the calcaneus were, in practice, arbitrarily divided into two groups in carrying out the above multivariate analyses because of a statistical restriction on sample size and the number of variables, namely, because the number of individuals was too small, particularly in females, compared with the total number of variables to obtain the solutions. As for the other foot bones, such treatment was not made because the number of variables was smaller than the number of individuals observed.

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

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

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
1	Length	29	50.7	2.1	20	45.6	1.9
2	Breadth	29	40.2	2.4	20	35.9	2.3
3	Height	29	30.3	1.5	20	27.0	1.5
3(1)	Medial height	29	31.9	1.8	20	28.1	1.9
K5	Lateral height	29	31.2	1.5	20	28.0	1.5
4	Length of trochlea	29	31.8	2.0	20	28.1	1.7
5	Middle breadth of trochlea	29	27.3	2.0	20	24.2	1.8
5(2)	Anterior breadth of trochlea	29	27.9	1.9	20	24.4	1.8
5(1)	Posterior breadth of trochlea	29	22.2	2.2	20	19.1	1.5
6	Height of trochlea	29	8.0	0.9	20	7.1	0.6
7	Total breadth of articular surface for lateral malleolus	29	22.8	2.2	20	22.4	1.8
7a	Projective breadth of articular surface for lateral malleolus	29	8.3	1.6	20	8.0	1.4
8	Length of neck plus head	29	22.8	1.8	20	20.7	1.5
9	Length of head	29	32.2	1.6	20	28.0	1.8
10	Breadth of head	29	21.3	1.8	20	18.9	1.7
11	Height of head	29	13.6	1.8	20	11.9	1.3
12	Length of posterior calcaneal articular surface	29	30.4	1.7	20	27.2	1.8
13	Maximum breadth of posterior calcaneal articular surface	29	20.7	1.3	20	18.8	1.1
14	Depth of posterior calcaneal articular surface	29	7.2	1.0	20	5.9	0.6
15	Deflection angle of posterior calcaneal articular surface	29	45.8	4.4	20	45.8	4.7
K21	Deflection angle of post. calcaneal art. surf. after Adachi	29	51.1	5.0	20	51.5	5.0
16	Deflection angle of neck	29	20.3	3.3	20	19.0	4.0
K23	Deflection angle of neck after Adachi	29	17.4	6.4	20	14.2	7.1
17	Torsion angle of head	28	43.2	4.4	20	40.6	4.9
K25	Torsion angle of head after Volkov	29	38.4	5.6	20	38.1	5.8

1) The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).

2) Bare-numbered variables are measurements according to Martin and Saller (1957), and those with the letter 'K' preceding the number are measurements according to Kiyono (1929).

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

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
1	Maximum length	29	72.4	3.4	20	66.6	3.8
1a	Physiological length	29	70.0	3.4	20	63.9	3.7
2	Middle breadth	29	40.7	2.4	20	36.3	2.6
3	Minimum breadth of body	29	26.2	2.1	20	23.1	2.0
4	Height	29	39.4	2.7	20	35.0	2.1
K6	Minimum height after Adachi	29	36.6	2.2	20	32.5	2.1
5	Length of body	29	53.0	2.5	20	48.8	3.6
6	Breadth of sustentaculum tali	29	13.3	1.9	20	11.2	1.3
7	Height of calcaneal tuber	25	44.1	2.8	20	39.2	2.4
8	Breadth of calcaneal tuber	29	30.5	1.9	20	26.3	2.2
9	Length of posterior articular surface	29	28.1	1.9	20	25.1	2.1
10	Breadth of posterior articular surface	29	20.9	1.8	20	18.6	1.3
11	Height of posterior articular surface	29	6.5	1.1	20	5.6	0.9
12	Maximum breadth of articular surface for cuboid	28	25.8	1.9	20	23.3	2.0
13	Height of articular surface for cuboid	28	20.5	1.9	20	18.7	2.1
14	Deflection angle of posterior articular surface	29	40.6	7.2	20	38.9	6.9
15	Talocalcaneal angle	29	−5.3	7.7	20	−6.9	5.9

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).
[2)] Bare-numbered variables are measurements according to Martin and Saller (1957), and those with the letter 'K' preceding the number are measurements according to Kiyono (1929).

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

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
1	Breadth	28	38.5	1.6	20	34.1	2.7
2	Height	28	28.4	2.2	20	25.9	2.7
3	Maximum length of posterior articular surface	28	27.7	1.6	20	24.6	1.5
4	Breadth of posterior articular surface	28	21.4	1.9	20	19.5	1.6
5	Depth of posterior articular surface	28	6.2	0.8	20	5.2	0.7
6	Maximum length of cuneiform facets	27	34.1	1.6	20	30.6	1.9
7	Minimum thickness	28	8.1	1.5	20	7.7	1.1
8	Maximum thickness	28	18.0	1.6	20	16.2	1.9

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).
[2)] Variable number according to Martin and Saller (1957).

Table 4. Means and standard deviations for the measurements of the right cuboid bone in Japanese males and females.[1)]

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
1	Medial length	29	29.1	2.0	20	26.8	2.0
2	Lateral length	29	14.7	2.4	20	13.7	1.3

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).
[2)] Variable number according to Martin and Saller (1957).

Table 5. Means and standard deviations for the measurements of the right cuneiform bones in Japanese males and females.[1)]

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
Medial (first) cuneiform:							
1	Inferior length	28	25.4	1.9	20	22.5	1.7
2	Middle length	29	21.3	1.6	20	20.1	1.7
3	Superior length	27	25.7	2.0	20	23.7	1.5
4	Height of proximal articular surface	26	19.4	1.6	20	17.7	1.3
5	Height of distal articular surface	28	27.9	1.8	20	25.4	1.7
6	Proximal height	28	24.6	2.7	20	21.3	1.5
7	Distal height	28	31.5	1.9	20	28.0	1.7
Intermediate (second) cuneiform:							
1	Superior length	29	17.2	1.5	20	15.8	1.2
2	Middle superior breadth	29	16.3	1.2	20	14.6	1.4
K3	Central height	29	20.4	1.3	20	18.3	1.5
Lateral (third) cuneiform:							
1	Superior length	29	22.3	1.3	20	20.3	1.4
2	Middle superior breadth	29	14.5	0.9	20	13.1	1.0
4	Proximal breadth	29	11.8	1.4	20	10.5	0.9
3	Distal breadth	29	13.1	1.2	20	12.0	1.0
K5	Central height	29	21.4	1.3	20	19.0	1.3

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).

[2)] Bare-numbered variables are measurements according to Martin and Saller (1957), and those with the letter 'K' preceding the number are measurements according to Kiyono (1929).

Table 6. Means and standard deviations for the measurements of the right metatarsal bones in Japanese males and females.[1)]

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
K2	Length of first metatarsal	29	54.7	2.7	20	51.7	2.6
K2	Length of second metatarsal	29	65.6	3.2	20	61.9	3.5
K2	Length of third metatarsal	29	63.4	3.4	20	59.8	3.6
K2	Length of fourth metatarsal	29	62.1	3.7	20	58.7	3.7
K2	Length of fifth metatarsal	29	59.0	3.2	20	55.7	3.3
11	Torsion angle of first metatarsal	29	2.4	5.4	20	2.4	4.2
11	Torsion angle of second metatarsal	28	−5.2	5.1	20	−3.6	3.7
11	Torsion angle of third metatarsal	29	16.1	4.8	20	18.5	4.2
11	Torsion angle of fourth metatarsal	29	15.6	5.7	20	21.4	4.2
11	Torsion angle of fifth metatarsal	29	10.3	5.5	20	10.8	6.8

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).

[2)] Bare-numbered variables are measurements according to Martin and Saller (1957), and those with the letter 'K' preceding the number are measurements according to Kiyono (1929).

Table 7. Means and standard deviations for the measurements of the right foot phalanges in Japanese males and females.[1)]

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
1	Length of proximal foot phalange I	29	26.1	2.1	20	23.1	2.6
1	Length of proximal foot phalange II	29	25.1	2.0	20	23.4	2.0
1	Length of proximal foot phalange III	29	23.7	1.7	20	22.1	1.9
1	Length of proximal foot phalange IV	29	22.2	1.7	20	20.9	1.7
1	Length of proximal foot phalange V	29	20.3	1.9	20	18.9	1.3
1	Length of intermediate foot phalange II	28	11.6	2.3	20	9.9	2.1
1	Length of intermediate foot phalange III	29	9.2	2.5	20	8.5	2.0
1	Length of intermediate foot phalange IV	28	8.5	2.4	20	7.8	2.5
1	Length of intermediate foot phalange V	29	10.7	3.7	19	10.7	3.4
1	Length of distal foot phalange I	29	21.6	1.8	20	20.1	1.7
1	Length of distal foot phalange II	26	10.0	1.6	19	9.3	1.6
1	Length of distal foot phalange III	29	9.8	1.6	19	9.2	1.8
1	Length of distal foot phalange IV	28	8.8	3.1	19	7.6	3.7
1	Length of distal foot phalange V	29	3.5	4.3	19	1.9	3.3

1) The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Hirai and Tabata (1928).

2) Variable number according to Martin and Saller (1957).

of a factor loading, 1,000 bootstrap replications including the observed sample were used. The bootstrap standard deviation was estimated by directly counting the cumulative frequency for the standard deviation in the bootstrap distribution.

The reality of a common factor such as represented by a principal component or rotated factor was further tested, though indirectly, by evaluating similarity between the factors obtained for males and females, i.e., by estimating a Spearman's rank correlation coefficient, rho (Siegel, 1956), between the variation patterns of the factor loadings.

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 were written in FORTRAN by the present author.

Results

The direct results of principal component analyses (PCAs) and the rotated solutions for the neurocranium and the talus are shown in Tables 8 to 11 and 13 to 16. And the degree of similarity, i.e., the Spearman's rank correlation coefficients, between males and females in the variation patterns of factor loadings on the principal components (PCs) and/or rotated factors extracted are shown in Tables 12 and 17. Similarly, the results for the other foot bones are shown in Tables 18 to 47.

First of all, the PCAs and the rotated solutions for the talus show that there is no PC nor rotated factor common to males and females such as is significantly correlated with both cranial length or breadth and one or more talar measurements (Tables 8 to 11 and 13 to 16). However, PC I's from the first data sets of both sexes were found to have significant correlations both with basi-bregmatic height and with many talar measurements (Tables 8, 10 and 12).

In the analyses for the calcaneus (Tables 18 to 21 and 23 to 26) , it was found that there was no PC nor rotated factor common to males and females which was significantly correlated both with one or more cranial measurements and with one or more calcaneal measurements. However,

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

	Variable[2)]	Factor loadings PC I	II	III	IV	V	Total variance (%)
1	Cranial length	.30	.34	−.28	.56	.51	85.26
8	Cranial breadth	.31	.27	−.51	−.62	.26	88.55
17	Basi-bregmatic height	.55*	.21	−.42	.43	−.09	70.65
1	Length	.92***	.07	.09	.06	−.03	86.65
2	Breadth	.87***	.10	.21	−.08	−.02	81.27
3	Height	.79***	−.37	−.28	−.03	−.24	89.42
3(1)	Medial height	.75***	−.40	−.21	−.02	−.34	87.25
K5	Lateral height	.86***	−.30	−.09	−.04	−.06	85.15
4	Length of trochlea	.49*	−.63	−.01	.09	.12	66.27
5	Middle br. of trochlea	.76***	.56	.05	−.09	−.01	90.71
5(2)	Ant. br. of trochlea	.70***	.57	−.07	−.21	.13	87.90
5(1)	Post. br. of trochlea	.57***	.53	.21	.06	−.13	67.03
6	Height of trochlea	−.16	−.52	−.60	−.13	.27	75.09
7	T. br. of a. s. for l. m.	.68**	−.51	.27	.14	.23	86.66
7a	P. br. of a. s. for l. m.	.45	−.33	.63	−.20	.39	89.22
Total contribution (%)		42.20	17.35	10.47	6.85	5.60	82.47
Cumulative proportion (%)		42.20	59.55	70.02	76.87	82.47	82.47

1) The sample size is 29. 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 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 talus from Japanese males.[1)]

	Variable[2)]	Factor loadings Fac I	II	III	IV	V
1	Cranial length	−.03	.15	−.08	.91*	.04
8	Cranial breadth	.10	.10	−.93*	.04	−.07
17	Basi-bregmatic height	.47	.28	−.03	.58*	−.27
1	Length	.61***	.59	−.11	.22	.29
2	Breadth	.51*	.63	−.16	.08	.35
3	Height	.92*	.12	−.15	.05	.07
3(1)	Medial height	.92*	.12	−.06	−.04	.05
K5	Lateral height	.82*	.24	−.17	.10	.30
4	Length of trochlea	.64	−.21	.05	.09	.45
5	Middle br. of trochlea	.24	.83	−.33	.22	.06
5(2)	Ant. br. of trochlea	.17	.72	−.51	.25	.07
5(1)	Post. br. of trochlea	.13	.79	−.05	.15	.01
6	Height of trochlea	.23	−.76	−.34	.11	−.03
7	T. br. of a. s. for l. m.	.59	.06	.13	.15	.69***
7a	P. br. of a. s. for l. m.	.15	.18	.01	−.14	.90***

1) The sample size is 29. The cumulative proportion of the variances of the five principal components is 82.47%.
2) See the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

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

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.20	.68	.50	−.01	.23	80.95
8	Cranial breadth	.25	−.51	−.71	−.21	−.07	86.53
17	Basi-bregmatic height	.50**	−.11	−.32	−.37	.65*	92.43
1	Length	.88***	.08	.00	.01	.15	79.51
2	Breadth	.90***	.12	.00	−.22	−.09	88.75
3	Height	.81***	−.25	−.02	.26	−.29	87.35
3(1)	Medial height	.84***	−.16	−.09	.32	−.22	89.45
K5	Lateral height	.85***	−.29	.29	−.05	−.11	90.52
4	Length of trochlea	.83***	−.39	−.06	.10	.20	90.35
5	Middle br. of trochlea	.69*	.56	−.16	−.13	−.30	92.19
5(2)	Ant. br. of trochlea	.81***	.46	−.18	−.15	−.07	92.58
5(1)	Post. br. of trochlea	.70***	.52	−.11	−.02	.05	76.68
6	Height of trochlea	.46	−.15	.13	.68	.35	83.21
7	T. br. of a. s. for l. m.	.57	−.34	.56	−.18	.04	78.58
7a	P. br. of a. s. for l. m.	.17	−.48	.52	−.47	−.12	75.50
Total contribution (%)		45.96	14.93	10.82	7.75	6.18	85.64
Cumulative proportion (%)		45.96	60.89	71.71	79.46	85.64	85.64

[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 1.

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

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

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.03	.34	.83	−.02	.08
8	Cranial breadth	−.00	.12	−.88	.05	.29
17	Basi-bregmatic height	.10	.25	−.16	.11	.90**
1	Length	.25	.63	.03	.47	.33
2	Breadth	.38	.80	−.05	.25	.22
3	Height	.32	.50*	−.29	.65***	−.13
3(1)	Medial height	.21	.56*	−.26	.68**	−.08
K5	Lateral height	.67	.45	−.09	.50	.07
4	Length of trochlea	.38	.33	−.27	.66*	.38
5	Middle br. of trochlea	−.03	.96	.06	.02	−.04
5(2)	Ant. br. of trochlea	.03	.93	.04	.15	.21
5(1)	Post. br. of trochlea	−.07	.80	.19	.20	.21
6	Height of trochlea	−.05	−.01	.16	.89	.13
7	T. br. of a. s. for l. m.	.80	.14	.13	.31	.11
7a	P. br. of a. s. for l. m.	.85***	−.12	−.04	−.11	.02

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 85.64%.

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

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

Table 12. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the first data sets of neurocranial and talar measurements.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.85***	—	—	—	.67**	.72**	—	—	—	—
II	—	.65**	—	—	—	—	.67**	—	.74**	—
III	—	—	—	—	—	—	—	—	—	.63*
IV	—	—	—	—	—	—	—	—	—	—
V	—	—	—	—	—	—	—	—	.54*	—
Fac I	—	—	—	—	—	.52*	—	—	—	.85***
II	.67**	.58*	—	—	.51*	—	.77***	—	—	—
III	—	—	—	—	—	—	—	—	.61*	—
IV	—	.71**	—	—	—	.73**	—	—	—	—
V	—	—	—	—	—	—	—	—	—	—

[1)] Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 8, 9, 10 and 11.

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

Table 13. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the talus from Japanese males.[1)]

	Variable[2)]	Factor loadings[3)]							Total variance (%)
		PC I	II	III	IV	V	VI	VII	
1	Cranial length	.24	.49	−.51	.10	−.23	.21	.14	68.73
8	Cranial breadth	.15	.60	−.06	.32	−.07	.33	.27	66.72
17	Basi-bregmatic height	.56	.11	−.36	.30	−.20	.14	−.48	82.93
8	Length of neck plus head	.81	.03	.22	−.02	.08	.02	−.30	79.78
9	Length of head	.76	.26	−.20	−.21	−.02	−.04	.09	73.86
10	Breadth of head	.65	.15	.18	−.27	.21	.16	.42	79.86
11	Height of head	.56	.14	.29	−.57	−.04	.38	-.09	89.73
12	Len. of post. cal. a. s.	.69	.21	.18	.31	−.00	−.39	.18	83.30
13	Max. br. of p. c. a. s.	.50	.65	−.04	.19	−.20	−.24	−.11	82.60
14	Depth of p. c. a. s.	.70	−.30	.05	−.44	.01	−.37	−.06	91.70
15	Def. ang. of p. c. a. s.	−.34	.72	.09	−.07	.49	−.12	−.09	90.62
K21	Def. ang. of p. c. a. s. after Adachi	−.31	.79	.02	−.04	.46	−.11	−.17	97.55
16	Def. ang. of neck	.37	−.31	.42	.34	.47	.34	−.16	87.95
K23	Def. ang. of neck after Adachi	.40	−.29	.43	.62	.07	−.08	.17	85.17
17	Tor. ang. of head	.34	−.41	−.68	.10	.33	.06	−.03	87.73
K25	Tor. ang. of head after Volkov	.25	−.30	−.68	.00	.43	−.07	.15	82.62
	Total contribution (%)	26.58	17.93	12.06	9.30	7.21	5.31	4.80	83.18
	Cumulative proportion (%)	26.58	44.51	56.56	65.86	73.07	78.38	83.18	83.18

[1)] The sample size is 28. 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.

[3)] No significant factor loading was found at the 5% level by two-tailed bootstrap tests.

Table 14. Solution obtained through the normal varimax rotation of the first seven principal components for the correlation matrix on the second set of measurements of the neurocranium and the talus from Japanese males.[1)]

Variable[2)]		Factor loadings						
		Fac I	II	III	IV	V	VI	VII
1	Cranial length	.11	.67***	−.19	−.33	.04	−.10	−.28
8	Cranial breadth	.06	.77***	.11	.06	.19	−.15	−.06
17	Basi-bregmatic height	.09	.21	−.20	.07	−.14	−.16	−.83***
8	Length of neck plus head	.58	−.11	−.02	.34	−.05	−.35	−.46
9	Length of head	.63	.20	−.25	−.14	−.02	−.41	−.25
10	Breadth of head	.76	.21	−.12	.17	−.01	−.28	.23
11	Height of head	.90*	.01	.19	.05	−.04	.11	−.16
12	Len. of post. cal. a. s.	.22	.11	−.02	.20	−.03	−.85***	−.12
13	Max. br. of p. c. a. s.	.19	.34	.15	−.16	.24	−.61*	−.44
14	Depth of p. c. a. s.	.61	−.50*	−.22	−.08	−.26	−.40	−.12
15	Def. ang. of p. c. a. s.	−.05	.11	.12	−.07	.93***	.01	.11
K21	Def. ang. of p. c. a. s. after Adachi	−.07	.15	.11	−.11	.96***	−.00	−.00
16	Def. ang. of neck	.18	−.09	−.08	.91**	−.04	.03	−.10
K23	Def. ang. of neck after Adachi	−.10	.02	.06	.70	−.31	−.50*	.05
17	Tor. ang. of head	.02	−.02	−.89	.09	−.19	.04	−.21
K25	Tor. ang. of head after Volkov	.02	−.01	−.91	−.03	−.05	−.03	.01

[1)] The sample size is 28. The cumulative proportion of the variances of the seven principal components is 83.18%.
[2)] See the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 15. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the talus from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.34	−.09	−.62	.10	.51	78.66
8	Cranial breadth	.12	.34	.70	−.39	−.26	83.47
17	Basi-bregmatic height	.47	.05	.61	−.22	.44	83.39
8	Length of neck plus head	.82**	−.01	−.26	.03	−.31	83.36
9	Length of head	.71	.49	−.36	−.07	−.11	87.98
10	Breadth of head	.85**	.05	.39	−.12	.10	89.42
11	Height of head	.44	.50	−.53	−.31	−.27	88.44
12	Len. of post. cal. a. s.	.79***	−.22	.10	.25	−.13	76.12
13	Max. br. of p. c. a. s.	.64*	.42	.23	−.02	−.15	66.29
14	Depth of p. c. a. s.	.56	.25	−.29	−.31	.16	58.08
15	Def. ang. of p. c. a. s.	−.09	.59	.15	.73*	−.17	95.01
K21	Def. ang. of p. c. a. s. after Adachi	−.08	.43	.03	.80*	−.09	83.99
16	Def. ang. of neck	.50	−.54	.02	.26	.32	70.56
K23	Def. ang. of neck after Adachi	.70*	−.13	.20	.48	.22	82.29
17	Tor. ang. of head	.33	−.76	.08	.02	−.43	88.94
K25	Tor. ang. of head after Volkov	.20	−.82	−.11	.10	−.36	86.40
Total contribution (%)		29.25	18.71	13.07	12.30	8.08	81.40
Cumulative proportion (%)		29.25	47.96	61.02	73.32	81.40	81.40

[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 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 16. 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 talus from Japanese females.[1)]

	Variable[2)]	Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.30	.07	.14	−.12	.81**
8	Cranial breadth	.09	.17	.28	−.10	−.84**
17	Basi-bregmatic height	−.02	.21	.83***	−.23	−.21
8	Length of neck plus head	.73	−.47	.26	.06	.08
9	Length of head	.90	.06	.19	.13	.09
10	Breadth of head	.40	−.14	.82***	−.09	−.18
11	Height of head	.91	.11	−.19	−.05	.00
12	Len. of post. cal. a. s.	.35	−.53	.57*	.15	.07
13	Max. br. of p. c. a. s.	.56	.02	.47	.20	−.31
14	Depth of p. c. a. s.	.65	.15	.24	−.23	.17
15	Def. ang. of p. c. a. s.	.02	.22	−.01	.94*	−.13
K21	Def. ang. of p. c. a. s. after Adachi	−.03	.12	−.01	.91*	.07
16	Def. ang. of neck	−.09	−.42	.56*	−.07	.45
K23	Def. ang. of neck after Adachi	.13	−.29	.75**	.32	.25
17	Tor. ang. of head	−.06	−.91*	.12	−.21	−.06
K25	Tor. ang. of head after Volkov	−.13	−.89	−.03	−.19	.15

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 81.40%.
[2)] See the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 17. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the second data sets of neurocranial and talar measurements.[1)]

		Male PC I	II	III	IV	V	VI	VII	Fac I	II	III	IV	V	VI	VII
Female PC	I	.87***	—	—	—	—	—	—	.63**	—	—	—	—	.69**	—
	II	—	.69**	—	.52*	—	—	—	—	—	.57*	.53*	.52*	—	—
	III	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	IV	—	—	—	—	.61*	—	—	.61*	—	—	—	—	—	—
	V	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fac	I	.71**	—	—	—	.51*	—	—	.76***	—	—	—	—	—	—
	II	—	.55*	—	—	—	—	—	—	—	—	—	—	—	—
	III	—	—	—	.54*	—	—	—	—	—	—	.51*	—	.60*	—
	IV	—	.59*	—	—	—	—	—	—	—	.67**	—	.51*	—	—
	V	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[1)] Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 13, 14, 15 and 16.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 18. Principal component analysis of the correlation matrix on the first set of measurements of the neurocranium and the calcaneus from Japanese males.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.39**	−.21	.11	.67	−.13	67.00
8	Cranial breadth	.29	−.37	−.02	−.09	.84*	93.27
17	Basi-bregmatic height	.49	.07	.41	.57	.05	74.27
1	Maximum length	.80***	−.40	−.32	.06	−.03	90.70
1a	Physiological length	.77***	−.38	−.46	.00	−.02	93.93
2	Middle breadth	.70***	−.34	.50	−.24	.01	91.52
3	Minimum breadth of body	.67***	.34	.42	.04	.19	77.78
4	Height	.77***	.42	−.25	−.12	−.09	86.51
K6	Min. height after Adachi	.84***	.36	.17	−.01	−.08	87.53
5	Length of body	.70***	−.51	−.30	.01	−.12	84.64
6	Br. of sustentaculum tali	.27	−.58	.46	−.38	−.36	89.53
7	Height of calcaneal tuber	.64*	.57	−.33	−.03	−.06	84.08
8	Br. of calcaneal tuber	.64**	.46	.13	−.32	.08	73.81
Total contribution (%)		40.85	16.63	11.05	8.57	7.10	84.20
Cumulative proportion (%)		40.85	57.47	68.53	77.09	84.20	84.20

[1)] The sample size is 25. 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 first set of measurements of the neurocranium and the calcaneus from Japanese males.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	−.05	−.32	.01	.75	−.07
8	Cranial breadth	−.01	−.24	.04	.02	.93*
17	Basi-bregmatic height	.27	−.02	.09	.81	.09
1	Maximum length	.23	−.88	.16	.19	.15
1a	Physiological length	.24	−.92	.08	.07	.14
2	Middle breadth	.34*	−.26	.78	.24	.27
3	Minimum breadth of body	.71	.07	.22	.41	.23
4	Height	.83*	−.40	−.09	.02	−.08
K6	Min. height after Adachi	.83*	−.22	.18	.32	−.02
5	Length of body	.11	−.86	.25	.14	.08
6	Br. of sustentaculum tali	−.10	−.20	.92	−.02	−.08
7	Height of calcaneal tuber	.81	−.29	−.29	.02	−.13
8	Br. of calcaneal tuber	.84	−.03	.15	−.04	.10

[1)] The sample size is 25. The cumulative proportion of the variances of the five principal components is 84.20%.
[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 calcaneus from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.37	−.51	−.45	.42	77.74
8	Cranial breadth	−.04	.90	.30	−.01	90.30
17	Basi-bregmatic height	.39**	.57	−.26	−.29	62.71
1	Maximum length	.92***	−.17	−.09	−.11	90.56
1a	Physiological length	.92***	−.06	−.18	−.05	89.26
2	Middle breadth	.79***	.30	−.25	.21	82.50
3	Minimum breadth of body	.74***	.22	.24	.46	85.52
4	Height	.81***	−.16	.40	−.31	94.85
K6	Min. height after Adachi	.63*	−.09	.58	−.04	75.41
5	Length of body	.87***	−.03	−.14	−.20	81.89
6	Br. of sustentaculum tali	.34	.18	−.63	−.35	66.68
7	Height of calcaneal tuber	.75**	−.42	.27	−.18	85.01
8	Br. of calcaneal tuber	.81***	.35	−.02	.38	93.04
Total contribution (%)		48.67	14.96	11.70	7.40	82.73
Cumulative proportion (%)		48.67	63.64	75.33	82.73	82.73

[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 four principal components for the correlation matrix on the first set of measurements of the neurocranium and the calcaneus from Japanese females.[1)]

Variable[2)]		Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.03	−.82	−.08	.32
8	Cranial breadth	−.17	.88	−.07	.31
17	Basi-bregmatic height	.07	.35	−.66	.25
1	Maximum length	.70	−.30	−.41	.40
1a	Physiological length	.59	−.26	−.48	.49
2	Middle breadth	.25	−.07	−.46	.74*
3	Minimum breadth of body	.38	.04	.06	.84**
4	Height	.95*	.04	−.13	.19
K6	Min. height after Adachi	.78	.13	.19	.30
5	Length of body	.63	−.16	−.51	.37
6	Br. of sustentaculum tali	−.00	−.12	−.81	.03
7	Height of calcaneal tuber	.87*	−.27	−.04	.15
8	Br. of calcaneal tuber	.29	.03	−.24	.89**

[1)] The sample size is 20. The cumulative proportion of the variances of the four principal components is 82.73%.
[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. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the first data sets of neurocranial and calcaneal measurements.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.71**	—	.56*	—	—	—	.64*	—	—	—
II	—	—	—	—	.68*	—	.60*	—	—	.62*
III	—	.57*	—	—	—	.64*	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	—
Fac I	.80***	—	—	—	—	.62*	—	—	—	—
II	—	—	—	—	—	—	.60*	—	—	—
III	—	.64*	—	—	—	—	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	.71**

[1)] Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 18, 19, 20 and 21.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 23. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the calcaneus from Japanese males.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.50	.05	−.42	−.08	.61	79.97
8	Cranial breadth	.22	.16	−.53	.73	−.21	92.56
17	Basi-bregmatic height	.53	.36	−.31	−.26	.27	64.74
9	Length of post. art. sur.	.80***	.03	.09	.03	−.25	71.26
10	Br. of post. art. sur.	.80***	.16	.08	−.03	.02	67.65
11	Ht. of post. art. sur.	.27	−.48	.73	−.09	.18	86.88
12	Max. br. of a.s. for cub.	.77***	.02	.08	−.24	−.46	85.99
13	Ht. of art. sur. for cub.	.39	−.24	.48	.64	.26	91.23
14	Defl. ang. of post. a. s.	−.14	.82	.40	.19	.11	89.86
15	Talocalcaneal angle	−.09	.85	.40	−.07	−.03	89.10
Total contribution (%)		26.94	18.63	16.47	11.19	8.69	81.92
Cumulative proportion (%)		26.94	45.57	62.04	73.24	81.92	81.92

[1)] The sample size is 28. 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 24. 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 calcaneus from Japanese males.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.06	−.15	.07	.08	.87
8	Cranial breadth	.11	−.06	.10	.95*	.06
17	Basi-bregmatic height	.33	.13	−.19	.04	.69
9	Length of post. art. sur.	.80	−.03	.20	.10	.14
10	Br. of post. art. sur.	.68	.10	.22	.02	.39
11	Ht. of post. art. sur.	.21	−.14	.63	−.62	−.13
12	Max. br. of a.s. for cub.	.92*	−.07	−.06	−.06	.03
13	Ht. of art. sur. for cub.	.13	.02	.94*	.10	.00
14	Defl. ang. of post. a. s.	−.09	.94	.08	.07	−.01
15	Talocalcaneal angle	.07	.93	−.12	−.08	−.03

[1)] The sample size is 28. The cumulative proportion of the variances of the five principal components is 81.92%.
[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. Principal component analysis of the correlation matrix on the second set of measurements of the neurocranium and the calcaneus from Japanese females.[1)]

Variable[2)]		Factor loadings[3)]					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	−.21	−.10	−.74	.55	−.01	90.08
8	Cranial breadth	−.08	.48	.79	−.07	.04	86.64
17	Basi-bregmatic height	−.41	.39	.38	.64	.13	88.59
9	Length of post. art. sur.	−.70	.50	−.22	.02	−.23	83.65
10	Br. of post. art. sur.	−.72	.40	−.13	−.15	.29	80.06
11	Ht. of post. art. sur.	−.64	−.36	.49	.17	−.03	80.85
12	Max. br. of a.s. for cub.	−.43	.68	−.32	−.31	−.27	91.76
13	Ht. of art. sur. for cub.	−.56	−.25	−.18	−.25	.68	93.11
14	Defl. ang. of post. a. s.	.72	.54	−.06	.01	.17	84.35
15	Talocalcaneal angle	.65	.54	−.11	.17	.33	86.51
Total contribution (%)		30.69	20.34	17.56	9.59	8.38	86.56
Cumulative proportion (%)		30.69	51.03	68.59	78.18	86.56	86.56

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.
3) No significant factor loading was found at the 5% level by two-tailed bootstrap tests.

Table 26. 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 calcaneus from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.00	.14	−.93	.15	.04
8	Cranial breadth	.06	.13	.79	.46	−.07
17	Basi-bregmatic height	−.05	.16	.04	.92	.01
9	Length of post. art. sur.	−.19	.85	−.12	.25	.05
10	Br. of post. art. sur.	−.11	.65	.03	.24	.55
11	Ht. of post. art. sur.	−.77	−.08	.17	.40	.16
12	Max. br. of a.s. for cub.	.09	.95*	.03	−.07	−.00
13	Ht. of art. sur. for cub.	−.24	.05	−.10	−.04	.93
14	Defl. ang. of post. a. s.	.88	−.07	.15	−.03	−.19
15	Talocalcaneal angle	.91	−.10	.02	.14	−.06

1) The sample size is 20. The cumulative proportion of the variances of the five principal components is 86.56%.
2) See the second footnote to Table 2.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 27. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the second data sets of neurocranial and calcaneal measurements.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.81**	—	—	—	—	.77**	—	—	—	—
II	—	—	—	—	.76*	—	—	—	—	—
III	—	—	—	—	—	—	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	—
V	—	—	—	—	—	—	.67*	—	—	—
Fac I	—	.72*	—	—	—	—	—	.73*	—	—
II	.87**	—	—	—	—	.75*	—	—	—	.68*
III	—	—	—	—	—	—	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	—
V	—	—	—	—	—	—	—	.66*	—	—

1) Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 23, 24, 25 and 26.

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

Table 28. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the navicular and cuboid bones from Japanese males.[1)]

Variable[2)]	Factor loadings						Total variance (%)
	PC I	II	III	IV	V	VI	
1 Cranial length	.19	.42	.49	−.55	.13	.22	81.75
8 Cranial breadth	.22	.52	.12	.52	−.04	.59	94.13
17 Basi-bregmatic height	.41	.54	.06	−.38	−.53	−.16	92.03
1 Breadth of navicular bone	.75***	−.39	.24	.07	−.11	.21	83.68
2 Height of navicular bone	.64**	−.19	−.48	−.29	.11	.21	81.47
3 Max.length of p. art. sur.	.73***	−.16	.36	.35	−.25	−.06	87.61
4 Br. of post. art. surface	.68**	−.43	−.04	−.36	.21	.18	85.71
5 Depth of post. art. sur.	.47*	−.09	.76	−.10	.03	−.23	86.63
6 Max. leng. of cun. facets	.90***	−.35	−.07	.12	.05	−.02	94.67
7 Min. thick. of nav. bone	.50*	.49	−.29	−.12	.39	−.07	75.27
8 Max. thick. of nav. bone	.60***	.19	−.11	.34	.28	−.40	76.35
1 Med. length of cub. bone	.65**	.55	−.01	.13	.16	−.07	77.48
2 Lat. length of cub. bone	.57**	.07	−.57	−.04	−.49	−.03	89.74
Total contribution (%)	35.47	14.28	12.93	9.40	7.14	5.90	85.12
Cumulative proportion (%)	35.47	49.76	62.69	72.09	79.22	85.12	85.12

1) The sample size is 27. 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 footnotes to Tables 3 and 4.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, 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 set of measurements of the neurocranium and the navicular and cuboid bones from Japanese males.[1)]

Variable[2)]		Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	.04	.07	−.04	−.89	−.09	.09
8	Cranial breadth	.09	.19	.09	−.07	−.03	.94**
17	Basi-bregmatic height	.13	.18	.05	−.39	−.85**	.00
1	Breadth of navicular bone	.71	−.02	−.55**	−.02	−.05	.15
2	Height of navicular bone	−.02	.23	−.85***	.05	−.20	−.01
3	Max.length of p. art. sur.	.87	.16	−.15	.09	−.17	.19
4	Br. of post. art. surface	.32	.07	−.83***	−.17	.05	−.15
5	Depth of post. art. sur.	.78*	.11	.04	−.46	.05	−.17
6	Max. leng. of cun. facets	.61	.32	−.65*	.18	−.09	.01
7	Min. thick. of nav. bone	−.16	.76	−.28	−.20	−.14	.10
8	Max. thick. of nav. bone	.33	.78***	−.08	.19	−.03	−.01
1	Med. length of cub. bone	.20	.73	−.10	−.19	−.25	.30
2	Lat. length of cub. bone	.04	.19	−.44	.34	−.74*	.08

1) The sample size is 27. The cumulative proportion of the variances of the six principal components is 85.12%.
2) See the second footnotes to Tables 3 and 4.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 30. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the navicular and cuboid bones from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.22	−.65	.34	.44	78.00
8	Cranial breadth	.22	.87	−.21	−.04	84.46
17	Basi-bregmatic height	.62***	.19	−.54	.32	81.12
1	Breadth of navicular bone	.91***	−.13	−.06	.06	84.24
2	Height of navicular bone	.75***	.18	.00	.37	73.14
3	Max.length of p. art. sur.	.69**	−.48	−.22	−.30	84.34
4	Br. of post. art. surface	.78***	.08	−.09	.38	77.58
5	Depth of post. art. sur.	.67***	−.56	−.31	−.14	87.97
6	Max. leng. of cun. facets	.91***	.16	.14	−.24	92.06
7	Min. thick. of nav. bone	.51*	.13	.68	−.29	81.89
8	Max. thick. of nav. bone	.89***	−.10	.14	−.26	88.33
1	Med. length of cub. bone	.60**	.35	−.10	−.27	56.11
2	Lat. length of cub. bone	.46	.29	.57	.31	71.07
Total contribution (%)		44.83	15.90	11.08	8.22	80.02
Cumulative proportion (%)		44.83	60.73	71.81	80.02	80.02

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 footnotes to Tables 3 and 4.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 31. Solution obtained through the normal varimax rotation of the first four principal components for the correlation matrix on the set of measurements of the neurocranium and the navicular and cuboid bones from Japanese females.[1)]

	Variable[2)]	Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.20	−.83	.16	−.13
8	Cranial breadth	.36	.81	.14	.21
17	Basi-bregmatic height	.79*	.25	−.17	−.31
1	Breadth of navicular bone	.58	−.03	.33	−.63
2	Height of navicular bone	.76*	.03	.33	−.21
3	Max.length of p. art. sur.	.15	−.11	.06	−.90***
4	Br. of post. art. surface	.79	−.02	.24	−.29
5	Depth of post. art. sur.	.26	−.22	−.07	−.87***
6	Max. leng. of cun. facets	.39	.26	.61	−.58
7	Min. thick. of nav. bone	−.04	.03	.88	−.20
8	Max. thick. of nav. bone	.30	.06	.54	−.70*
1	Med. length of cub. bone	.29	.49	.32	−.37
2	Lat. length of cub. bone	.41	−.08	.71	.18

1) The sample size is 20. The cumulative proportion of the variances of the four principal components is 80.02%.
2) See the second footnotes to Tables 3 and 4.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 32. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the sets of measurements of the neurocranium and the navicular and cuboid bones.[1)]

	Male PC I	II	III	IV	V	VI	Fac I	II	III	IV	V	VI
Female PC I	.81***	.71**	—	—	—	—	.59*	—	.56*	—	—	—
II	—	—	—	—	—	—	—	—	—	—	—	—
III	—	—	.59*	—	—	—	—	—	—	—	—	—
IV	—	—	—	.71**	—	—	—	—	—	—	—	—
Fac I	—	—	—	—	—	—	—	—	—	—	—	—
II	—	—	—	—	—	—	—	.62*	—	—	—	—
III	—	—	.75**	—	—	—	—	—	.59*	—	—	—
IV	—	—	—	—	—	—	.87***	—	—	—	—	—

1) Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 28, 29, 30 and 31.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 33. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the medial (C1), intermediate (C2) and lateral (C3) cuneiform bones from Japanese males.[1)]

	Variable[2)]	Factor loadings						Total variance (%)
		PC I	II	III	IV	V	VI	
1	Cranial length	.27	.33	−.05	.71	−.36	.02	80.91
8	Cranial breadth	.32	.17	.21	.36	.46	.40	68.09
17	Basi-bregmatic height	.38	−.40	−.03	.53	−.51	−.07	85.63
1	Inferior length (C1)	.82***	−.18	.08	.05	.05	.21	76.06
2	Middle length (C1)	.87***	−.10	.10	−.12	.10	.17	82.81
3	Superior length (C1)	.73***	−.20	−.31	−.30	−.23	.37	94.04
4	Ht. of prox. a. s. (C1)	.17	.93**	−.12	−.04	−.04	.05	90.39
5	Ht. of dist. a. s. (C1)	.78***	.16	.02	−.08	.12	−.47	86.85
6	Proximal height (C1)	.42	.77*	−.09	.20	.23	−.02	86.90
7	Distal height (C1)	.87***	.16	−.02	.04	.09	−.24	85.15
1	Superior length (C2)	.86***	−.30	−.15	−.10	.14	.05	88.41
2	Middle sup. br. (C2)	.78***	−.42	−.13	−.00	−.04	−.17	82.72
K3	Central height (C2)	.78***	.13	−.37	−.03	−.11	−.14	78.42
1	Superior length (C3)	.69***	−.05	−.43	.02	.22	−.02	70.97
2	Middle sup. br. (C3)	.58***	.20	.44	−.13	−.34	.28	77.98
4	Proximal breadth (C3)	.31	−.44	.57	.31	.35	−.17	86.81
3	Distal breadth (C3)	.39	.30	.58	−.36	−.29	−.21	83.36
K5	Central height (C3)	.81***	.08	.29	−.08	−.05	.07	76.07
Total contribution (%)		41.68	13.83	8.22	7.37	6.40	4.81	82.31
Cumulative proportion (%)		41.68	55.51	63.73	71.10	77.50	82.31	82.31

[1)] The sample size is 26. 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 5.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 34. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the set of measurements of the neurocranium and the medial (C1), intermediate (C2) and lateral (C3) cuneiform bones from Japanese males.[1)]

	Variable[2)]	Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	.02	.38	.04	.80	.14	−.00
8	Cranial breadth	.13	.20	.02	.04	.78	−.09
17	Basi-bregmatic height	.30	−.32	.06	.81**	−.05	−.05
1	Inferior length (C1)	.71*	−.07	.30	.16	.36	−.01
2	Middle length (C1)	.76**	.00	.39	.00	.31	−.02
3	Superior length (C1)	.79	−.10	.25	.04	.03	.50*
4	Ht. of prox. a. s. (C1)	−.04	.91*	.21	−.02	.00	.18
5	Ht. of dist. a. s. (C1)	.68	.34	.28	.02	−.11	−.45
6	Proximal height (C1)	.21	.86	.08	.07	.26	−.10
7	Distal height (C1)	.75**	.33	.27	.14	.07	−.28
1	Superior length (C2)	.91**	−.11	.13	.02	.18	−.04
2	Middle sup. br. (C2)	.83**	−.23	.11	.19	−.03	−.17
K3	Central height (C2)	.78*	.33	.10	.20	−.13	.04
1	Superior length (C3)	.80*	.19	−.16	.04	.10	.00
2	Middle sup. br. (C3)	.25	.09	.78*	.16	.20	.15
4	Proximal breadth (C3)	.17	−.40	.16	.10	.44	−.67***
3	Distal breadth (C3)	.08	.17	.85	−.07	−.16	−.21
K5	Central height (C3)	.58*	.12	.58	.10	.23	−.10

[1)] The sample size is 26. The cumulative proportion of the variances of the six principal components is 82.31%.
[2)] See the second footnote to Table 5.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 35. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the medial (C1), intermediate (C2) and lateral (C3) cuneiform bones from Japanese females.[1)]

	Variable[2)]	Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.13	.83	.09	.41	88.86
8	Cranial breadth	.23	−.77	−.22	−.11	71.50
17	Basi-bregmatic height	.62***	−.36	.08	.42	68.69
1	Inferior length (C1)	.87***	.18	−.23	−.19	87.75
2	Middle length (C1)	.77***	.33	−.23	−.28	84.28
3	Superior length (C1)	.77**	.21	−.33	−.36	86.84
4	Ht. of prox. a. s. (C1)	.54**	−.10	.67	−.34	86.75
5	Ht. of dist. a. s. (C1)	.89***	−.03	−.06	−.11	80.10
6	Proximal height (C1)	.63***	.04	.62	−.19	81.17
7	Distal height (C1)	.89***	−.22	−.04	−.01	84.92
1	Superior length (C2)	.90***	.32	−.11	.11	93.60
2	Middle sup. br. (C2)	.80***	.35	−.12	−.12	80.06
K3	Central height (C2)	.86***	−.01	.34	.09	86.15
1	Superior length (C3)	.83***	.06	−.14	.26	78.51
2	Middle sup. br. (C3)	.77***	−.36	−.25	−.05	77.80
4	Proximal breadth (C3)	.70***	−.25	−.11	.38	71.75
3	Distal breadth (C3)	.73***	−.19	.05	.13	58.76
K5	Central height (C3)	.87***	−.05	.25	.18	86.03
Total contribution (%)		55.13	11.82	7.89	5.92	80.75
Cumulative proportion (%)		55.13	66.94	74.83	80.75	80.75

[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 5.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 36. Solution obtained through the normal varimax rotation of the first four principal components for the correlation matrix on the set of measurements of the neurocranium and the medial (C1), intermediate (C2) and lateral (C3) cuneiform bones from Japanese females.[1)]

	Variable[2)]	Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.17	.92	−.04	.09
8	Cranial breadth	.03	−.78	−.03	.33
17	Basi-bregmatic height	.08	−.13	.18	.79
1	Inferior length (C1)	.85*	−.00	.19	.34
2	Middle length (C1)	.88*	.09	.19	.17
3	Superior length (C1)	.91*	−.07	.13	.15
4	Ht. of prox. a. s. (C1)	.17	−.10	.90	.12
5	Ht. of dist. a. s. (C1)	.67*	−.11	.33	.48
6	Proximal height (C1)	.24	.07	.83	.24
7	Distal height (C1)	.56	−.23	.33	.62
1	Superior length (C2)	.74*	.27	.20	.53
2	Middle sup. br. (C2)	.78*	.21	.24	.29
K3	Central height (C2)	.39	.08	.59	.59
1	Superior length (C3)	.55	.11	.11	.68
2	Middle sup. br. (C3)	.54	−.41	.11	.56
4	Proximal breadth (C3)	.28	−.10	.06	.79
3	Distal breadth (C3)	.35	−.13	.28	.61
K5	Central height (C3)	.38	.06	.49	.68

[1)] The sample size is 20. The cumulative proportion of the variances of the four principal components is 80.75%.
[2)] See the second footnote to Table 5.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 37. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the sets of measurements of the neurocranium and the cuneiform bones.[1]

	Male PC I	II	III	IV	V	VI	Fac I	II	III	IV	V	VI
Female PC I	.88***	—	—	—	—	—	.74***	—	—	—	—	—
II	—	—	.52*	—	—	—	.49*	—	—	—	—	—
III	—	—	—	—	—	.47*	—	.54*	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	—	—	—
Fac I	.80***	—	—	.56*	—	—	.78***	—	—	—	—	—
II	—	—	.55*	—	—	—	—	—	—	—	—	—
III	—	—	—	—	—	—	—	—	—	—	—	—
IV	—	—	—	—	—	—	—	—	—	—	—	—

[1] Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 33, 34, 35 and 36.

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

Table 38. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the metatarsal bones from Japanese males.[1]

	Variable[2]	Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.36	.66	−.16	−.35	.13	72.88
8	Cranial breadth	.29	−.20	.43	−.50	.43	73.29
17	Basi-bregmatic height	.43	.31	.16	−.46	.09	52.93
K2	Length of 1st metatarsal	.87***	.12	.08	.15	−.07	81.00
K2	Length of 2nd metatarsal	.89***	−.10	.21	.17	−.17	91.18
K2	Length of 3rd metatarsal	.95***	−.06	.17	.11	−.04	94.76
K2	Length of 4th metatarsal	.93***	.00	.16	.10	−.06	89.82
K2	Length of 5th metatarsal	.91***	.00	.06	.15	−.12	87.60
11	Torsion angle of 1st met.	.30	.36	−.32	.48	.65	97.46
11	Torsion angle of 2nd met.	−.23	−.07	.83	.15	.20	80.39
11	Torsion angle of 3rd met.	−.67***	.08	.46	.19	−.12	71.89
11	Torsion angle of 4th met.	−.50	.67*	.32	.28	.05	87.74
11	Torsion angle of 5th met.	−.01	.86***	.09	−.10	−.33	85.74
Total contribution (%)		41.52	14.69	11.15	8.19	6.49	82.05
Cumulative proportion (%)		41.52	56.22	67.37	75.56	82.05	82.05

[1] The sample size is 28. 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 6.

* $P<0.05$; ** $P<0.01$; *** $P<0.001$, 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 set of measurements of the neurocranium and the metatarsal bones from Japanese males.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.13	.72	−.28	−.25	.23
8	Cranial breadth	.15	−.08	.09	−.83	−.04
17	Basi-bregmatic height	.27	.45*	−.12	−.49	−.04
K2	Length of 1st metatarsal	.86***	.15	−.13	−.07	.14
K2	Length of 2nd metatarsal	.95***	−.03	−.06	−.08	−.02
K2	Length of 3rd metatarsal	.94***	.00	−.12	−.19	.07
K2	Length of 4th metatarsal	.92***	.07	−.12	−.17	.08
K2	Length of 5th metatarsal	.91***	.06	−.18	−.06	.08
11	Torsion angle of 1st met.	.17	.08	−.08	.07	.96*
11	Torsion angle of 2nd met.	−.01	−.15	.84	−.27	−.06
11	Torsion angle of 3rd met.	−.43	−.00	.67	.20	−.20
11	Torsion angle of 4th met.	−.34	.49	.64	.25	.22
11	Torsion angle of 5th met.	.02	.89	.15	.20	−.06

1) The sample size is 28. The cumulative proportion of the variances of the five principal components is 82.05%.
2) See the second footnote to Table 6.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

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

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.08	.72	.02	.31	61.64
8	Cranial breadth	.33	−.65	−.02	−.56	84.90
17	Basi-bregmatic height	.60***	−.21	−.41	−.21	61.48
K2	Length of 1st metatarsal	.91***	.06	.20	.19	90.06
K2	Length of 2nd metatarsal	.96***	.03	−.03	.11	94.48
K2	Length of 3rd metatarsal	.98***	.06	−.03	−.07	97.02
K2	Length of 4th metatarsal	.97***	.12	−.06	−.00	96.48
K2	Length of 5th metatarsal	.94***	.17	−.03	−.09	91.26
11	Torsion angle of 1st met.	.00	.36	.83	−.07	82.39
11	Torsion angle of 2nd met.	−.34	−.60	−.29	.43	73.56
11	Torsion angle of 3rd met.	.26	−.61	.36	.47	79.99
11	Torsion angle of 4th met.	.07	−.71	.53	−.24	84.62
11	Torsion angle of 5th met.	−.35	.39	.03	−.57	60.71
Total contribution (%)		40.88	19.70	10.78	10.07	81.43
Cumulative proportion (%)		40.88	60.58	71.36	81.43	81.43

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 6.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

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

	Variable[2)]	Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.16	.72	.22	−.13
8	Cranial breadth	.27	−.86	−.19	−.06
17	Basi-bregmatic height	.59**	−.25	−.45	−.06
K2	Length of 1st metatarsal	.88***	.04	.20	.28
K2	Length of 2nd metatarsal	.95***	.02	−.03	.19
K2	Length of 3rd metatarsal	.98***	−.07	−.01	.03
K2	Length of 4th metatarsal	.98***	.02	−.02	.05
K2	Length of 5th metatarsal	.95***	.01	.03	−.04
11	Torsion angle of 1st met.	.02	.07	.90	−.08
11	Torsion angle of 2nd met.	−.43*	−.12	−.47	.56
11	Torsion angle of 3rd met.	.12	−.29	.14	.82
11	Torsion angle of 4th met.	−.04	−.81	.30	.31
11	Torsion angle of 5th met.	−.26	−.01	.17	−.71

[1)] The sample size is 20. The cumulative proportion of the variances of the four principal components is 81.43%.
[2)] See the second footnote to Table 6.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 42. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the sets of measurements of the neurocranium and the metatarsal bones.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.84***	—	—	—	—	.83***	—	.55*	—	—
II	—	—	.87***	—	—	—	—	.63*	—	—
III	—	—	—	.57*	—	—	—	—	.73**	—
IV	—	—	—	—	—	—	—	—	—	—
Fac I	.91***	—	—	—	—	.87***	—	.69**	—	—
II	—	—	.81***	—	—	—	—	.65*	—	.62*
III	—	.74**	.58*	—	—	—	.64*	—	.71**	.68*
IV	—	—	.68*	—	—	—	—	—	—	—

[1)] Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 38, 39, 40 and 41.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 43. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the foot phalanges from Japanese males.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.35	.06	.32	.57	.51	81.11
8	Cranial breadth	.23	−.22	.56	−.17	−.17	47.64
17	Basi-bregmatic height	.26	−.38	.35	.55	.28	72.50
1	Length of prox. f. ph. I	.86***	−.09	−.02	.03	−.05	75.92
1	Length of prox. f. ph. II	.90***	−.07	.15	.12	−.22	89.84
1	Length of prox. f. ph. III	.91***	−.04	.18	.06	−.11	87.84
1	Length of prox. f. ph. IV	.85***	.08	.27	.05	−.31	89.69
1	Length of prox. f. ph. V	.83***	.14	.17	−.03	−.28	81.77
1	Length of int. f. ph. II	.84***	−.05	−.32	.08	.06	82.67
1	Length of int. f. ph. III	.82***	−.24	−.18	−.09	.08	76.67
1	Length of int. f. ph. IV	.15	−.43	.46	−.60	.33	87.92
1	Length of int. f. ph. V	−.26	.82	.33	.02	−.13	86.96
1	Length of dist. f. ph. I	.74***	.31	−.08	−.26	−.18	75.63
1	Length of dist. f. ph. II	.33	.67	.18	−.28	.40	82.78
1	Length of dist. f. ph. III	.56**	.46	−.09	−.26	.51*	86.33
1	Length of dist. f. ph. IV	.66***	.40	−.49	.23	.06	89.26
1	Length of dist. f. ph. V	.53*	−.63	−.34	−.26	.20	90.81
Total contribution (%)		42.30	14.51	9.20	8.17	7.31	81.49
Cumulative proportion (%)		42.30	56.81	66.01	74.19	81.49	81.49

1) The sample size is 25. 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 7.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 44. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the set of measurements of the neurocranium and the foot phalanges from Japanese males.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.15	.04	−.06	.85	.25
8	Cranial breadth	.32	.07	.59	.09	−.12
17	Basi-bregmatic height	.14	−.16	.12	.80	−.17
1	Length of prox. f. ph. I	.77**	−.33	−.02	.16	.16
1	Length of prox. f. ph. II	.91***	−.17	.05	.21	.03
1	Length of prox. f. ph. III	.87***	−.19	.09	.23	.15
1	Length of prox. f. ph. IV	.93***	.02	.12	.12	.06
1	Length of prox. f. ph. V	.89***	−.00	.06	.03	.15
1	Length of int. f. ph. II	.67*	−.48	−.29	.12	.24
1	Length of int. f. ph. III	.63*	−.57	−.02	.09	.20
1	Length of int. f. ph. IV	−.02	−.35	.84	.01	.23
1	Length of int. f. ph. V	−.04	.87	−.06	−.11	.29
1	Length of dist. f. ph. I	.74**	−.06	−.06	−.23	.38
1	Length of dist. f. ph. II	.18	.27	.06	.02	.85***
1	Length of dist. f. ph. III	.28	−.12	−.09	.06	.87**
1	Length of dist. f. ph. IV	.53*	−.15	−.66	.06	.39
1	Length of dist. f. ph. V	.26	−.91	.11	−.01	.04

1) The sample size is 25. The cumulative proportion of the variances of the five principal components is 81.49%.
2) See the second footnote to Table 7.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 45. Principal component analysis of the correlation matrix on the set of measurements of the neurocranium and the foot phalanges from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.03	−.01	−.83	.15	.40	86.89
8	Cranial breadth	.13	.34	.81	−.15	.06	82.55
17	Basi-bregmatic height	.32	.67	.05	−.16	.30	66.43
1	Length of prox. f. ph. I	.60*	−.30	.09	.04	−.65	87.20
1	Length of prox. f. ph. II	.91***	.13	.03	−.05	−.13	86.60
1	Length of prox. f. ph. III	.93***	.21	−.12	.01	−.00	93.00
1	Length of prox. f. ph. IV	.93***	.19	.07	.01	−.03	91.01
1	Length of prox. f. ph. V	.92***	.27	.11	−.08	−.03	93.29
1	Length of int. f. ph. II	.69***	−.38	−.33	−.03	−.22	77.76
1	Length of int. f. ph. III	.67***	−.53	−.30	.12	.04	83.51
1	Length of int. f. ph. IV	−.08	.18	.10	.95*	.02	94.21
1	Length of int. f. ph. V	.00	.75	−.51	−.03	−.34	94.65
1	Length of dist. f. ph. I	.81***	−.08	−.10	.08	.08	69.05
1	Length of dist. f. ph. II	.79***	.22	.08	.19	.22	76.15
1	Length of dist. f. ph. III	.82***	.17	.19	.32	.06	84.16
1	Length of dist. f. ph. IV	.74**	−.21	−.13	−.48	.25	91.09
1	Length of dist. f. ph. V	.37	−.74	.44	.12	.25	95.73
Total contribution (%)		43.87	14.84	12.46	8.15	6.17	85.49
Cumulative proportion (%)		43.87	58.71	71.17	79.32	85.49	85.49

[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 7.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 46. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the set of measurements of the neurocranium and the foot phalanges from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.06	.15	−.88	.01	.25
8	Cranial breadth	.24	−.09	.83	−.01	.25
17	Basi-bregmatic height	.50*	.35	.17	−.09	.50
1	Length of prox. f. ph. I	.41	−.08	.13	−.04	−.82
1	Length of prox. f. ph. II	.88***	.03	.06	−.15	−.26
1	Length of prox. f. ph. III	.94***	.09	−.10	−.11	−.14
1	Length of prox. f. ph. IV	.93***	.01	.07	−.08	−.16
1	Length of prox. f. ph. V	.93***	.06	.15	−.15	−.10
1	Length of int. f. ph. II	.51	−.15	−.38	−.22	−.55
1	Length of int. f. ph. III	.50	−.41	−.50	−.11	−.40
1	Length of int. f. ph. IV	.06	−.01	−.05	.97	.05
1	Length of int. f. ph. V	.14	.95	−.14	.05	.00
1	Length of dist. f. ph. I	.77**	−.17	−.19	−.07	−.17
1	Length of dist. f. ph. II	.86	−.08	−.00	.11	.10
1	Length of dist. f. ph. III	.87	−.12	.09	.24	−.08
1	Length of dist. f. ph. IV	.63	−.26	−.19	−.64	−.03
1	Length of dist. f. ph. V	.22*	−.93	.06	−.01	−.18

[1)] The sample size is 18. The cumulative proportion of the variances of the five principal components is 85.49%.
[2)] See the second footnote to Table 7.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 47. Spearman's rank correlation coefficients between males and females in the variation pattern of factor loadings on the principal components and/or rotated factors obtained from the sets of measurements of the neurocranium and the foot phalanges.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.77***	—	—	—	—	.81***	—	—	—	—
II	—	—	.79***	—	—	—	.70**	—	—	—
III	—	—	—	.57*	—	—	—	.58*	—	—
IV	—	—	—	.59*	.57*	—	—	—	—	—
V	—	—	—	—	.55*	—	—	—	—	—
Fac I	.67**	—	—	—	—	.73***	—	—	—	—
II	—	—	.73***	—	—	—	—	—	—	—
III	—	—	—	—	—	—	—	.62**	—	.55*
IV	.64**	—	—	.57*	.49*	.63**	—	—	—	—
V	.76***	—	.68**	—	—	.65**	.62**	—	—	—

[1)] Only those rank correlation coefficients significant at the 5% level are listed here. The signs of rank correlation coefficients are removed because the signs of factor loadings are reversible. The original factor loadings are listed in Tables 43, 44, 45 and 46.

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

PC I from the first data set of males is significantly correlated with cranial length and many calcaneal measurements (Table 18), and, on the other hand, PC I of females is significantly correlated with basi-bregmatic height and many calcaneal measurements (Table 20). The Spearman's rank correlation coefficient of 0.71 between these PC I's is significant at the 1% level (Table 22).

The analyses for the navicular and cuboid bones (Tables 28 to 32) show that there is no PC nor rotated factor common to males and females which is significantly correlated both with one or more cranial measurements and with one or more measurements of the navicular or cuboid. But PC I from females has significant correlations not only with basi-bregmatic height but also with all the measurements of the navicular and the medial length of the cuboid (Table 30).

Also regarding the cuneiform bones (Tables 33 to 37), there is no PC nor rotated factor common to males and females which is significantly correlated both with one or more cranial measurements and with one or more measurements of the cuneiforms. However, PC I from females, again, has significant correlations with basi-bregmatic height and all the measurements of the cuneiforms (Table 35).

Further, also in the analyses for the metatarsal bones (Tables 38 to 42), it was found that there was no PC nor rotated factor common to males and females which was significantly correlated both with one or more cranial measurements and with one or more measurements of the metatarsals. In this case, PC I and the first rotated factor from females have significant correlations both with basi-bregmatic height and with the lengths of all the metatarsals (Tables 40 and 41).

The final results of the analyses to be presented are those for the foot phalanges (Tables 43 to 47). They also show that there is no PC nor rotated factor common to males and females which is significantly correlated both with one or more cranial measurements and with one or more measurements of the foot phalanges. However, again, only one factor from females, i.e., the first rotated factor from females was found to be significantly correlated both with basi-bregmatic height and with the lengths of some phalanges, i.e., the second to fifth proximal phalanges and the first and fifth distal phalanges (Table 46).

Discussion

In the present study, it was found that neither cranial length nor breadth was consistently associated with any measurements of the foot bones. This, therefore, seems not to make any contribution to solving the problem of brachycephaliza-

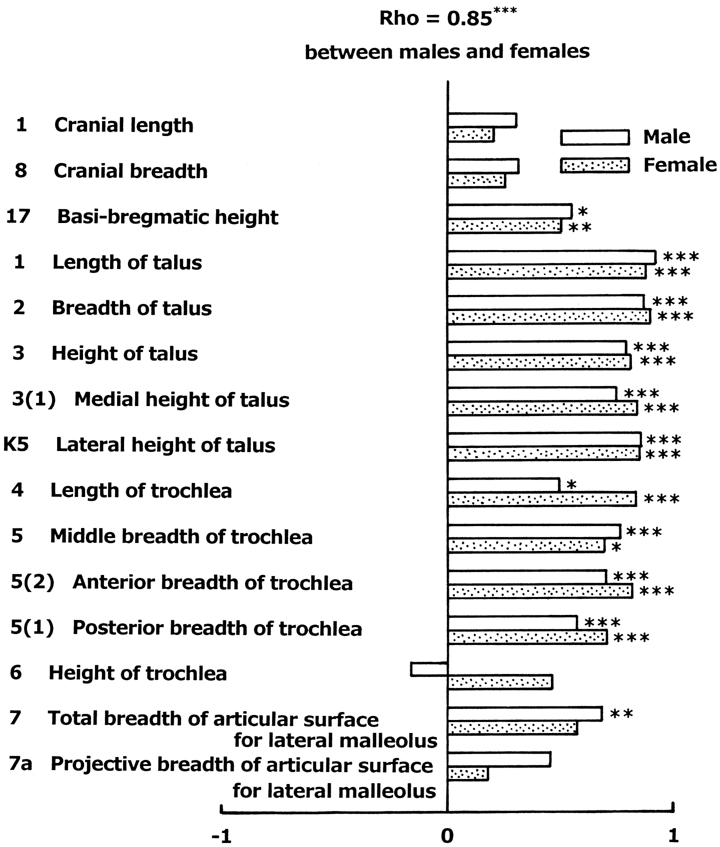

Fig. 1. Factor loadings on the first principal components obtained from the first data sets of the neurocranium and the talus of males and females. For the numbers preceding measurement items, see the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$.

tion. But, apart from this, an interesting result was found. It is that basi-bregmatic height is significantly associated with many measurements of the talus (Tables 8, 10 and 12; Fig. 1). And, further, the results for all the other foot bones suggest that basi-bregmatic height is strongly associated with the size of the foot bones at least in females (Tables 20, 30, 35, 40 and 46).

As for the associations with basi-bregmatic height, a preliminary analysis by the present author (Mizoguchi, 1992) has suggested that basi-bregmatic height may be associated with the breadth of the talus. But, except this, only the transverse diameters of the vertebral foramina have been shown to be strongly associated with this cranial height through a series of multivariate analyses by the present author (Mizoguchi, 1994, 1995, 1996, 1997, 1998a, b, 1999, 2000, 2001, 2002, 2003a, b, c).

The causes for the associations between basi-bregmatic height and the transverse diameters of the vertebral foramina still remain to be specified (Mizoguchi, 1998a). Also regarding the new findings in the present analyses, it seems difficult to find their causes. Mizoguchi (1992), using the anthropometric data on males reported by Hoshi and Kouchi (1978), showed that PC I extracted from them was relatively highly correlated both with cranial length and with foot length and breadth, and that PC VI, which was relatively highly correlated with auricular height, did not have any high correlation with either of foot length and breadth. These results do not support the present findings. As far as the present author knows, however, there are no other reports on the correlations between cranial and talar or foot bone measurements. For the present, therefore, the strong associations found here between basi-bregmatic height and the size of the foot bones may be only provisionally interpreted as a result of adaptation and/or adjustment (or accomodation) to balancing the posture of the body including the head, as already speculated by Mizoguchi (1992). If so, this should be a biomechanical adaptation and/or adjustment (or accomodation). But, even so, it is unknown whether the height of the head partly determines the size of the foot bones or the reverse causation is the case.

In the future, much more detailed analyses should be conducted to understand the meaning of the above findings.

Summary and Conclusions

Multivariate analyses on the neurocranium and the foot bones showed that, while neither cranial length nor breadth was consistently associated with any measurements of the foot bones, basi-bregmatic height was significantly associated with the size of the talus in both males and females and, only in females, also with the size of the other foot bones. As a cause for the strong associations between basi-bregmatic height and the size of the foot bones, adaptation and/or adjustment (or accomodation) to balancing the posture of the body including the head was suggested. But this is a problem to be further examined in the future.

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