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Significant Associations between Cranial Length and Pelvic Measurements: Toward the Solution of the Brachycephalization Problem

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Abstract As a step toward elucidating the causes of brachycephalization, correlations between neurocranial and pelvic measurements were examined using principal component analysis and Kaiser's normal varimax rotation methods. The results show that, while cranial breadth has no systematic relation with any pelvic measurements, cranial length is significantly associated with the height of the innominate, maximum pelvic breadth, and anterior upper spinal breadth in both sexes. These findings support the previous suggestion from the analyses of the sacrum that the form of the maternal pelvic inlet has been and is still one of the most important determinants for the neurocranial form, and suggest the possibility that one of the causes for brachycephalization may be a secular change in the shape of the pelvis.

Key words : Brachycephalization, Neurocranium, Pelvis, Principal component analysis, Bootstrap method

Since 1992, the present author has examined correlations between cranial and postcranial measurements in order to clarify the causes of brachycephalization. Using principal component analysis and Kaiser's normal varimax rotation methods, the author found 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 heights, femoral lengths and thicknesses, and tibial lengths and thicknesses. Findings also showed that cranial breadth has no consistent association with any measurements of the vertebrae, ribs, sternum, scapula, clavicle, humerus, ulna, radius, pelvis, femur, patella, tibia, fibula or foot bones. In turn it showed that basi-bregmatic height is significantly associated with the transverse diameters of the vertebral foramina of almost all the vertebrae and with the size of the talus. The details of these results have already been published (Mizoguchi, 1992, 1994, 1995, 1996, 1997, 1998a, b, 1999, 2000, 2001, 2002, 2003b, c, 2004). Only those on the pelvis have not been fully described, though briefly presented at an international symposium (Mizoguchi, 2003a). Therefore, the detailed results of the analyses on the pelvis are given here to complete this series of multivariate analyses.

Materials and Methods

The data used are the raw measurements of the neurocranium reported by Miyamoto (1924) and those of the pelvis reported by Miyamoto (1927) and Tabata (1930). 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 pelvic measurements are listed in Table 1.

For examining the overall relations between the neurocranial and pelvic measurements, principal component analysis (Lawley and Maxwell,

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

Variable[2)]		Males			Females		
		n	Mean	SD	*n*	Mean	SD
K1	Physiological pelvic height	30	199.7	9.7	20	188.3	9.7
K2	Physiological pelvic depth	30	143.1	6.7	20	142.8	7.9
1	Height of innominate	29	206.3	9.8	20	189.9	9.7
K4	Height of innominate	30	190.7	9.6	20	174.9	9.0
2	Maximum pelvic breadth	30	258.8	13.8	20	251.9	14.4
3	Maximum pelvic depth	27	161.3	9.7	20	167.6	9.9
3(1)	Lumbo-pubic depth	28	173.4	9.8	20	178.2	9.2
5	Anterior upper spinal breadth	30	224.0	13.6	20	218.6	15.2
5(1)	Anterior lower spinal breadth	30	180.6	9.8	20	175.3	10.8
6	Posterior upper spinal breadth	30	70.3	9.3	19	77.5	7.3
7	Acetabular breadth	30	118.9	5.7	20	123.4	5.5
19	Inter-obturator breadth	30	45.6	3.9	20	51.9	5.4
23	Sagittal diameter of pelvic inlet	30	100.2	7.7	20	109.2	7.7
24	Transverse diameter of pelvic inlet	30	120.3	5.5	19	123.9	6.2
25	Oblique diameter of pelvic inlet	30	118.2	4.5	20	122.0	6.3
26(1)	Sagittal diameter of pelvic outlet	30	108.0	7.4	20	115.8	10.3
8	Breadth between ischial spines	30	82.9	5.6	19	97.4	6.9
27	Transverse diameter of pelvic outlet	30	93.7	6.4	20	110.0	6.9
27a	Transverse diameter of pelvic outlet	30	109.2	8.8	20	127.1	9.2
28	Side height of true pelvis	30	93.2	4.8	20	83.1	4.8
29	Anterior height of true pelvis	30	117.3	6.1	20	115.0	5.8
30	True height of true pelvis	30	128.5	7.1	20	123.7	8.3
18	Length of pubic symphysis	30	34.2	3.7	20	32.0	4.5
1	Anterior arc of sacrum	30	113.9	10.2	19	112.3	8.0
2	Anterior length of sacrum	30	101.2	11.3	19	100.4	9.2
5	Anterior superior breadth of sacrum	30	99.8	4.5	20	99.4	7.5
6	Maximum depth of anterior concavity of sacrum	30	20.4	6.0	19	19.1	3.9
7	Position of maximum depth from promontory	30	64.9	10.5	19	64.3	7.2
23(2)	Inferior sagittal diameter of true pelvis	30	115.2	8.2	20	121.7	8.4
23(1)	Normal sagittal diameter of true pelvis	30	122.9	11.6	20	130.8	10.9
9	Iliac height	30	126.1	5.8	20	119.0	5.7
10	Height of iliac blade	30	98.5	5.3	20	95.3	6.0
K28	Height of iliac blade	30	97.4	5.8	20	90.6	5.8
12	Iliac breadth	30	149.2	6.6	20	144.7	8.3
13	Breadth of iliac blade	30	89.0	5.1	20	89.3	5.7
4	Maximum breadth of innominate	29	167.2	11.6	20	169.6	8.7
17	Pubis length	30	82.7	4.4	20	84.4	5.3
15	Ischium length	30	83.6	4.7	20	75.7	4.4
11	Depth of iliac fossa	30	7.7	2.1	20	4.5	1.3
20	Length of obturator foramen	30	51.5	3.6	20	47.8	3.0
21	Breadth of obturator foramen	30	32.5	2.9	20	33.4	2.1
14	Acetabulo-symphysial breadth	30	113.7	4.8	20	112.2	6.2
22	Maximum diameter of acetabulum	30	54.0	2.4	20	50.4	2.7
31	Breadth of greater sciatic notch	30	54.4	6.6	19	62.5	3.2
32	Depth of greater sciatic notch	30	36.5	2.8	19	34.2	2.4
34(1)	Divergence angle of iliac blade	30	87.8	7.4	20	84.6	9.5
34	Inclination angle of iliac blade	29	113.3	7.1	20	114.4	4.8
33	Subpubic angle	30	58.1	9.1	20	77.7	8.4
35	Inclination angle of pelvis	30	63.2	5.2	19	64.1	4.0
K44	Inclination angle of lumbo-pubic depth	28	54.4	3.6	20	57.0	4.4
36	Sacral inclination angle	30	43.1	10.2	20	44.9	10.4
W	α-angle (angle between pubis and ilium axes)	28	171.3	4.9	18	169.2	5.6
W	β-angle (angle between pubis and ischium axes)	28	84.2	3.1	18	81.6	4.3
W	γ-angle (angle between ilium and ischium axes)	28	104.5	4.2	18	109.2	6.0

[1)] The estimates of basic statistics listed here were recalculated by the present author on the basis of the raw data published by Miyamoto (1927) and Tabata (1930). When measurements are available for both sides, only those on the right side were used.

[2)] Bare-numbered variables are measurements according to Martin and Saller (1957), and those with the letter 'K' preceding the number are according to Kiyono (1929). 'W' designates a measurement defined by F. Weidenreich (Tabata, 1930).

1963; Okuno *et al.*, 1971, 1976; Takeuchi and Yanai, 1972) was applied to the correlation matrices on them. The number of principal components was determined so 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.

The measurements of the pelvis were, in practice, arbitrarily divided into four groups to carry out the above multivariate analyses. This was necessary because of a statistical restriction on sample size given the number of variables.

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 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 those 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, at the Computer Centre, University of Tokyo. The programs used were 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 pelvis are shown in Tables 2 to 17. And the Spearman's rank correlation coefficients between males and females for the variation pattern of factor loadings on the principal components (PCs) and/or rotated factors extracted are shown in Tables 18 to 21.

First of all, the PCAs and the rotated solutions for the pelvis show that cranial length is significantly associated with the height of the innominate, maximum pelvic breadth, and anterior upper spinal breadth in both sexes. This can be confirmed by comparing the first PC extracted from the first data set of males (Table 2) with the first rotated factor from the first data set of females (Table 5). These two factors from males and females are highly significantly correlated at the 0.1% level, as shown by the Spearman's rank correlation coefficient of 0.82 (Table 18).

On the other hand, regarding cranial breadth and basi-bregmatic height, there is no such PC or rotated factor, common to males and females, as is significantly correlated with both the breadth or height and one or more pelvic measurements (Tables 2 to 17).

Discussion

In the present study, it was found that cranial length had significant associations with the height of the innominate, maximum pelvic breadth, and anterior upper spinal breadth in both sexes (Tables 2 and 5). The two factors causing these associations, independently extracted from males and females, have significantly similar patterns of variation in their factor loadings (Table 18). These findings strongly suggest the tight connection in shape of the neurocranium and the pelvis.

Within-population variations

This tight connection between the neurocranium and the pelvis had already been suggested by Mizoguchi (1992) in his preliminary analysis using the same male sample as in the present study. In that analysis, a rotated factor, which was

Table 2. Principal component analysis of the correlation matrix on the first set of neurocranial and pelvic measurements from Japanese males.[1)]

Variable[2)]		Factor loadings PC I	II	III	IV	V	Total variance (%)
1	Cranial length	.61***	.07	.26	−.57	.02	76.65
8	Cranial breadth	.45*	.32	.64	.12	−.35	84.41
17	Basi-bregmatic height	.44*	−.48	.31	−.43	.08	70.31
K1	Physiological pelvic height	.89***	−.13	−.19	.15	.19	90.43
K2	Physiological pelvic depth	.49*	−.34	−.39	−.45	−.21	75.71
1	Height of innominate	.95***	−.07	−.09	.06	.16	94.06
K4	Height of innominate	.90***	.01	−.02	.02	.11	81.58
2	Maximum pelvic breadth	.78***	.46	.22	−.08	−.07	87.17
3	Maximum pelvic depth	.70***	−.59	.13	.12	−.03	87.06
3(1)	Lumbo-pubic depth	.63***	−.59	.02	.25	.18	83.76
5	Anterior upper spinal breadth	.75***	.45	.13	.22	−.28	91.80
5(1)	Anterior lower spinal breadth	.72***	.47	−.24	−.02	.02	79.57
6	Posterior upper spinal breadth	.27	−.54	−.07	.40	−.46	73.94
7	Acetabular breadth	.41	.32	−.68	−.09	−.31	83.90
19	Inter-obturator breadth	.36	.36	−.03	.22	.56	61.98
Total contribution (%)		42.95	15.48	9.17	7.36	6.53	81.49
Cumulative proportion (%)		42.95	58.43	67.60	74.96	81.49	81.49

[1)] The sample size is 24. 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 3. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the first set of neurocranial and pelvic measurements from Japanese males.[1)]

Variable[2)]		Factor loadings Fac I	II	III	IV	V
1	Cranial length	.36	−.02	−.15	−.77*	.16
8	Cranial breadth	.90**	−.08	.15	−.11	−.03
17	Basi-bregmatic height	.03	−.38	.13	−.74*	−.05
K1	Physiological pelvic height	.20	−.65	−.36	−.22	.50**
K2	Physiological pelvic depth	−.14	−.34	−.58	−.52	−.14
1	Height of innominate	.31	−.60	−.35	−.33	.50**
K4	Height of innominate	.38	−.50	−.32	−.33	.46*
2	Maximum pelvic breadth	.73	−.07	−.29	−.31	.39
3	Maximum pelvic depth	.15	−.85	−.01	−.35	.04
3(1)	Lumbo-pubic depth	−.01	−.87	.03	−.20	.22
5	Anterior upper spinal breadth	.82	−.21	−.36	.01	.26
5(1)	Anterior lower spinal breadth	.44	−.07	−.58*	−.12	.50*
6	Posterior upper spinal breadth	.10	−.73	−.11	.18	−.39
7	Acetabular breadth	.11	−.00	−.90*	.07	.08
19	Inter-obturator breadth	.13	−.02	−.02	.06	.77

[1)] The sample size is 24. The cumulative proportion of the variances of the five principal components is 81.49%.
[2)] See the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

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

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.42	−.33	−.68	−.08	.15	77.75
8	Cranial breadth	−.01	.86	.38	.03	−.07	88.24
17	Basi-bregmatic height	.29	.69	−.26	.05	−.39	78.88
K1	Physiological pelvic height	.73*	−.28	.04	.16	−.47	86.23
K2	Physiological pelvic depth	.73***	−.32	.12	.42	.01	81.81
1	Height of innominate	.97***	.10	.01	−.12	−.05	97.07
K4	Height of innominate	.93***	.11	−.01	−.16	−.02	89.74
2	Maximum pelvic breadth	.85***	.07	−.13	−.25	.09	81.08
3	Maximum pelvic depth	.73***	.37	−.04	.40	.31	94.01
3(1)	Lumbo-pubic depth	.76***	.36	.12	.41	.29	96.12
5	Anterior upper spinal breadth	.62***	.04	−.53	−.46	−.09	88.22
5(1)	Anterior lower spinal breadth	.83***	−.25	.26	−.19	.03	85.90
6	Posterior upper spinal breadth	.09	−.61	−.19	.54	−.23	76.06
7	Acetabular breadth	.32	−.45	.62	−.27	.33	87.36
19	Inter-obturator breadth	.32	−.13	.70	−.14	−.38	78.16
Total contribution (%)		41.75	16.28	13.23	8.45	6.08	85.78
Cumulative proportion (%)		41.75	58.02	71.25	79.70	85.78	85.78

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 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 five principal components for the correlation matrix on the first set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.66**	−.43	.05	.07	.38
8	Cranial breadth	−.25	.70	−.42	.32	−.22
17	Basi-bregmatic height	.25	.24	−.78**	.24	−.08
K1	Physiological pelvic height	.43	−.51*	−.13	.28	−.57
K2	Physiological pelvic depth	.22	−.52	.16	.61	−.31
1	Height of innominate	.72*	−.02	−.03	.56	−.38
K4	Height of innominate	.72*	.01	−.01	.52	−.33
2	Maximum pelvic breadth	.77*	.04	.05	.43	−.17
3	Maximum pelvic depth	.25	.02	−.12	.93***	.04
3(1)	Lumbo-pubic depth	.19	.05	−.07	.95***	−.09
5	Anterior upper spinal breadth	.92*	−.02	−.16	.03	.06
5(1)	Anterior lower spinal breadth	.57	−.11	.34	.39	−.50
6	Posterior upper spinal breadth	−.11	−.86*	.01	.04	−.04
7	Acetabular breadth	.11	.06	.81	.13	−.43
19	Inter-obturator breadth	.00	.05	.16	.04	−.87*

1) The sample size is 19. The cumulative proportion of the variances of the five principal components is 85.78%.

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 neurocranial and pelvic measurements from Japanese males.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.30	−.44	.49	−.07	.27	59.42
8	Cranial breadth	.22	.26	.43	−.71	−.05	80.32
17	Basi-bregmatic height	.39	−.39	.23	−.23	.60	77.33
23	Sagittal diameter of pelvic inlet	.66**	.15	−.64	−.21	.10	92.15
24	Transverse diameter of pelvic inlet	.44*	.04	.40	.72	.00	86.66
25	Oblique diameter of pelvic inlet	.70***	−.06	−.10	.58	.07	84.45
26(1)	Sagittal diameter of pelvic outlet	.69***	−.17	.07	−.10	−.54	80.69
8	Breadth between ischial spines	.27	.85	.31	.12	−.04	90.32
27	Transverse diameter of pelvic outlet	.37	.86	.17	.04	.18	93.59
27a	Transverse diameter of pelvic outlet	.42	.77	−.00	−.08	.16	80.23
28	Side height of true pelvis	.81***	−.42	.20	.03	.01	87.05
29	Anterior height of true pelvis	.77***	−.09	.32	−.01	−.27	77.37
30	True height of true pelvis	.84***	−.13	−.26	.06	.11	80.90
18	Length of pubic symphysis	.82***	−.09	.09	−.16	.11	73.00
23(2)	Inferior sagittal diam. of true pelvis	.66***	.07	−.61	−.01	.12	83.49
23(1)	Normal sagittal diam. of true pelvis	.83***	−.06	−.08	−.23	−.28	82.46
Total contribution (%)		37.63	17.08	11.18	9.79	6.16	81.84
Cumulative proportion (%)		37.63	54.71	65.89	75.68	81.84	81.84

[1)] The sample size is 30. 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 five principal components for the correlation matrix on the second set of neurocranial and pelvic measurements from Japanese males.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.24	−.12	.17	.11	.69
8	Cranial breadth	.37	.43	.15	−.61	.29
17	Basi-bregmatic height	.03	−.07	−.19	−.02	.86
23	Sagittal diameter of pelvic inlet	.21	.15	−.92	−.08	−.02
24	Transverse diameter of pelvic inlet	.26	.25	.15	.83	.16
25	Oblique diameter of pelvic inlet	.30	.11	−.42	.74	.14
26(1)	Sagittal diameter of pelvic outlet	.87*	−.02	−.19	.07	−.01
8	Breadth between ischial spines	.11	.92	.08	.13	−.15
27	Transverse diameter of pelvic outlet	.02	.95	−.14	.08	−.01
27a	Transverse diameter of pelvic outlet	.04	.84	−.31	−.02	−.03
28	Side height of true pelvis	.65*	−.09	−.27	.30	.53
29	Anterior height of true pelvis	.79	.18	−.10	.21	.26
30	True height of true pelvis	.42	.06	−.68	.29	.29
18	Length of pubic symphysis	.53*	.20	−.42	.09	.47
23(2)	Inferior sagittal diam. of true pelvis	.18	.09	−.88	.12	−.00
23(1)	Normal sagittal diam. of true pelvis	.76*	.12	−.47	−.02	.13

[1)] The sample size is 30. The cumulative proportion of the variances of the five principal components is 81.84%.
[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 second set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings				Total variance (%)
		PC I	II	III	IV	
1	Cranial length	.52*	−.50	−.27	−.47	81.56
8	Cranial breadth	−.04	.43	.78	.31	88.65
17	Basi-bregmatic height	.45	.01	.58	.24	59.37
23	Sagittal diameter of pelvic inlet	.59	.47	.48	−.30	88.63
24	Transverse diameter of pelvic inlet	.76*	.04	−.42	.30	84.10
25	Oblique diameter of pelvic inlet	.86**	−.08	−.29	.13	84.52
26(1)	Sagittal diameter of pelvic outlet	.82***	−.02	−.16	−.28	76.70
8	Breadth between ischial spines	−.15	.73	−.58	−.13	91.14
27	Transverse diameter of pelvic outlet	−.08	.91*	−.26	−.10	90.48
27a	Transverse diameter of pelvic outlet	.04	.86	−.40	.11	90.69
28	Side height of true pelvis	.88***	−.07	−.08	.22	83.00
29	Anterior height of true pelvis	.85***	.06	−.19	.30	85.72
30	True height of true pelvis	.84***	.10	.24	−.19	81.10
18	Length of pubic symphysis	.78**	−.24	−.22	.29	80.01
23(2)	Inferior sagittal diam. of true pelvis	.67	.50	.46	−.14	92.21
23(1)	Normal sagittal diam. of true pelvis	.88***	−.02	.15	−.28	87.70
Total contribution (%)		42.82	19.25	15.49	6.54	84.10
Cumulative proportion (%)		42.82	62.07	77.56	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 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 four principal components for the correlation matrix on the second set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings			
		Fac I	II	III	IV
1	Cranial length	.33	−.32	.23	−.75
8	Cranial breadth	−.21	−.03	.39	.83
17	Basi-bregmatic height	.26	−.33	.47	.45
23	Sagittal diameter of pelvic inlet	.10	.14	.91*	.15
24	Transverse diameter of pelvic inlet	.89*	.17	.09	−.11
25	Oblique diameter of pelvic inlet	.85*	−.01	.26	−.22
26(1)	Sagittal diameter of pelvic outlet	.57	.01	.53	−.41
8	Breadth between ischial spines	−.04	.94	−.10	−.14
27	Transverse diameter of pelvic outlet	−.11	.92	.17	.12
27a	Transverse diameter of pelvic outlet	.14	.93	.03	.16
28	Side height of true pelvis	.84*	−.10	.34	−.03
29	Anterior height of true pelvis	.88*	.06	.27	.01
30	True height of true pelvis	.48	−.10	.75*	−.08
18	Length of pubic symphysis	.86	−.18	.11	−.11
23(2)	Inferior sagittal diam. of true pelvis	.25	.16	.88*	.25
23(1)	Normal sagittal diam. of true pelvis	.51	−.15	.73*	−.25

[1)] The sample size is 18. The cumulative proportion of the variances of the four principal components is 84.10%.
[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 third set of neurocranial and pelvic measurements from Japanese males.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.50**	.44	−.32	.20	.52	85.72
8	Cranial breadth	.29	.62	.19	−.57	−.15	85.24
17	Basi-bregmatic height	.31	.61	−.44	.27	−.23	78.70
9	Iliac height	.90***	.10	−.03	−.05	.08	83.84
10	Height of iliac blade	.89***	.10	.01	−.09	.23	86.41
K28	Height of iliac blade	.94***	.03	−.04	−.06	.17	91.57
12	Iliac breadth	.85***	.08	.02	.07	−.17	77.11
13	Breadth of iliac blade	.82***	.13	−.04	.05	−.32	79.93
4	Maximum breadth of innominate	.80***	−.02	.24	−.13	−.35	82.92
17	Pubis length	.80***	−.23	.13	−.17	.17	77.21
15	Ischium length	.81***	−.25	.07	−.04	.14	74.18
11	Depth of iliac fossa	.34	.04	.39	.76	−.12	86.78
20	Length of obturator foramen	.54**	−.34	−.46	.08	−.08	63.18
21	Breadth of obturator foramen	.46	−.47	−.54	−.12	−.21	78.39
14	Acetabulo-symphysial breadth	.84***	−.23	.34	.03	.12	89.84
22	Maximum diameter of acetabulum	.81***	.02	.05	.08	−.09	66.68
Total contribution (%)		51.54	9.43	7.40	6.93	5.17	80.48
Cumulative proportion (%)		51.54	60.98	68.38	75.31	80.48	80.48

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 11. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the third set of neurocranial and pelvic measurements from Japanese males.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.28	.28	−.02	.03	.84*
8	Cranial breadth	.39*	.44	.46	−.55*	−.05
17	Basi-bregmatic height	.02	.83	−.09	.07	.30
9	Iliac height	.82**	.25	−.17	−.01	.28
10	Height of iliac blade	.83**	.14	−.11	−.05	.38
K28	Height of iliac blade	.85**	.16	−.21	−.01	.34
12	Iliac breadth	.76**	.36	−.19	.14	.07
13	Breadth of iliac blade	.71*	.49	−.22	.10	−.02
4	Maximum breadth of innominate	.83**	.27	−.09	.03	−.25
17	Pubis length	.83**	−.13	−.21	−.04	.14
15	Ischium length	.79*	−.09	−.28	.07	.16
11	Depth of iliac fossa	.30	.16	.14	.85	.01
20	Length of obturator foramen	.34	.11	−.70*	.05	.12
21	Breadth of obturator foramen	.29	.06	−.82**	−.13	−.06
14	Acetabulo-symphysial breadth	.91**	−.14	−.08	.21	.07
22	Maximum diameter of acetabulum	.73**	.26	−.18	.15	.09

1) The sample size is 29. The cumulative proportion of the variances of the five principal components is 80.48%.
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. Principal component analysis of the correlation matrix on the third set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings					Total variance (%)
		PC I	II	III	IV	V	
1	Cranial length	.29	−.77	.07	.06	.39	83.76
8	Cranial breadth	.14	.79	.19	.24	−.36	86.21
17	Basi-bregmatic height	.38**	.31	.72	.30	.19	88.29
9	Iliac height	.94***	−.05	.16	−.07	.02	91.31
10	Height of iliac blade	.84***	−.07	−.22	.13	−.07	77.77
K28	Height of iliac blade	.85***	−.04	−.28	−.01	−.02	80.94
12	Iliac breadth	.94***	−.01	.04	−.11	−.10	91.25
13	Breadth of iliac blade	.67**	−.22	.43	−.33	−.22	84.34
4	Maximum breadth of innominate	.88***	−.12	−.01	.01	−.24	84.45
17	Pubis length	.76***	−.00	−.47	.12	−.19	84.95
15	Ischium length	.86***	−.03	.07	−.22	.16	80.99
11	Depth of iliac fossa	−.13	.54	−.45	−.51	.31	87.39
20	Length of obturator foramen	.55*	.54	.07	−.21	.35	76.66
21	Breadth of obturator foramen	.49*	.15	−.20	.59	.48	88.43
14	Acetabulo-symphysial breadth	.89***	.07	−.31	.16	−.15	94.56
22	Maximum diameter of acetabulum	.78***	.08	.25	−.22	.17	75.75
Total contribution (%)		49.63	12.51	9.63	6.76	6.29	84.82
Cumulative proportion (%)		49.63	62.14	71.77	78.53	84.82	84.82

[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 13. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the third set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings				
		Fac I	II	III	IV	V
1	Cranial length	.18	−.83	.14	−.16	−.28
8	Cranial breadth	.09	.90	.11	−.19	−.02
17	Basi-bregmatic height	−.04	.28	.31	−.78*	−.31
9	Iliac height	.74*	−.10	.03	−.59*	−.07
10	Height of iliac blade	.84**	−.05	.18	−.18	−.06
K28	Height of iliac blade	.86**	−.09	.13	−.19	.09
12	Iliac breadth	.82**	−.02	−.04	−.48*	−.02
13	Breadth of iliac blade	.49	−.13	−.42	−.60*	−.23
4	Maximum breadth of innominate	.84**	−.02	−.06	−.31	−.19
17	Pubis length	.90*	.03	.16	.07	.06
15	Ischium length	.66*	−.19	.02	−.57*	.13
11	Depth of iliac fossa	−.07	.14	−.01	.08	.92*
20	Length of obturator foramen	.29	.21	.23	−.60	.48
21	Breadth of obturator foramen	.36	−.04	.86***	−.15	.01
14	Acetabulo-symphysial breadth	.94**	.09	.21	−.14	−.00
22	Maximum diameter of acetabulum	.51	−.07	.00	−.69**	.10

[1)] The sample size is 20. The cumulative proportion of the variances of the five principal components is 84.82%.
[2)] See the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 14. Principal component analysis of the correlation matrix on the fourth set of neurocranial and pelvic measurements from Japanese males.[1)]

	Variable[2)]	Factor loadings						Total variance (%)
		PC I	II	III	IV	V	VI	
1	Cranial length	.19	.45	.41	.28	.16	.54	80.00
8	Cranial breadth	.27	.11	.13	−.06	.83**	.04	80.20
17	Basi-bregmatic height	.45	.34	−.19	.53	.02	.41	81.12
31	Breadth of greater sciatic notch	.14	.51	−.21	.51	−.07	−.44	79.22
32	Depth of greater sciatic notch	−.41	−.05	.05	.66	.28	−.29	77.50
34(1)	Divergence angle of iliac blade	.71	.40	.24	−.36	−.03	−.19	89.08
34	Inclination angle of iliac blade	−.43	−.46	−.46	.46	−.12	.23	88.65
33	Subpubic angle	−.31	.02	−.24	−.05	.73*	−.05	69.74
35	Inclination angle of pelvis	.27	−.40	−.64	−.36	.25	.17	86.59
K44	Incl. angle of lumbo-pubic depth	.57	−.24	−.57	.01	.08	−.11	72.93
36	Sacral inclination angle	−.76	.16	.03	−.34	−.14	.20	78.67
W	α-angle (between pub. and ilium)	.39	−.71	.51	.19	.01	−.01	95.28
W	β-angle (between pub. and isch.)	−.69	.32	.10	−.18	.22	−.06	67.19
W	γ-angle (between ilium and isch.)	.05	.59	−.67	−.10	−.17	.05	83.63
Total contribution (%)		20.73	15.48	14.67	12.34	10.90	6.58	80.70
Cumulative proportion (%)		20.73	36.22	50.88	63.22	74.12	80.70	80.70

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

Table 15. Solution obtained through the normal varimax rotation of the first six principal components for the correlation matrix on the fourth set of neurocranial and pelvic measurements from Japanese males.[1)]

	Variable[2)]	Factor loadings					
		Fac I	II	III	IV	V	VI
1	Cranial length	−.21	.19	.07	.02	.07	.84**
8	Cranial breadth	.12	.30	.15	−.02	.79	.23
17	Basi-bregmatic height	.39	−.06	−.21	.18	−.05	.76*
31	Breadth of greater sciatic notch	.16	.10	−.35	.79***	−.07	.11
32	Depth of greater sciatic notch	−.17	−.47	.19	.65*	.27	−.00
34(1)	Divergence angle of iliac blade	.23	.90***	−.05	−.00	−.07	.11
34	Inclination angle of iliac blade	.11	−.93***	−.03	−.00	−.09	−.04
33	Subpubic angle	−.10	−.20	−.14	.02	.78	−.12
35	Inclination angle of pelvis	.61**	−.16	−.21	−.53*	.30	−.24
K44	Incl. angle of lumbo-pubic depth	.83**	.00	−.16	−.06	.08	−.12
36	Sacral inclination angle	−.74	−.23	−.28	−.28	−.04	−.18
W	α-angle (between pub. and ilium)	.31	.01	.91**	−.07	−.13	.02
W	β-angle (between pub. and isch.)	−.70	−.08	−.23	.05	.30	−.15
W	γ-angle (between ilium and isch.)	.15	.05	−.89*	.05	−.07	.08

1) The sample size is 26. The cumulative proportion of the variances of the six principal components is 80.70%.
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. Principal component analysis of the correlation matrix on the fourth set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings PC I	II	III	IV	V	Total variance (%)
1	Cranial length	−.43	.69	−.25	−.04	.26	79.90
8	Cranial breadth	−.02	−.66	−.03	.58	−.26	83.97
17	Basi-bregmatic height	−.47	−.28	−.39	.55	−.16	77.28
31	Breadth of greater sciatic notch	−.40	.34	.75	.29	−.11	92.81
32	Depth of greater sciatic notch	−.44	−.38	−.21	.54	.46	88.38
34(1)	Divergence angle of iliac blade	−.86	−.24	.09	−.05	.03	80.48
34	Inclination angle of iliac blade	.72	.23	−.14	.05	−.51	85.78
33	Subpubic angle	.71	−.22	.20	.28	.17	69.82
35	Inclination angle of pelvis	−.55	−.32	−.48	−.22	−.40	84.24
K44	Incl. angle of lumbo-pubic depth	−.88	.05	−.13	−.31	−.15	91.43
36	Sacral inclination angle	.81	−.33	.02	−.00	−.12	78.31
W	α-angle (between pub. and ilium)	.32	−.77	−.12	−.43	.25	95.05
W	β-angle (between pub. and isch.)	−.61	−.28	.60	−.02	−.22	86.27
W	γ-angle (between ilium and isch.)	.13	.84	−.29	.38	−.07	95.77
Total contribution (%)		33.97	21.43	11.34	11.17	7.05	84.96
Cumulative proportion (%)		33.97	55.41	66.75	77.92	84.96	84.96

[1)] The sample size is 16. 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 17. Solution obtained through the normal varimax rotation of the first five principal components for the correlation matrix on the fourth set of neurocranial and pelvic measurements from Japanese females.[1)]

Variable[2)]		Factor loadings Fac I	II	III	IV	V
1	Cranial length	−.34	.70	−.07	−.30	.31
8	Cranial breadth	.14	−.30	.11	.85**	−.02
17	Basi-bregmatic height	−.30	.15	−.05	.78	.22
31	Breadth of greater sciatic notch	.03	.29	.91	−.06	.10
32	Depth of greater sciatic notch	−.01	.01	−.05	.57	.75*
34(1)	Divergence angle of iliac blade	−.64	−.13	.36	.18	.47
34	Inclination angle of iliac blade	.35	.16	−.24	.01	−.81**
33	Subpubic angle	.79	−.21	−.09	.10	−.12
35	Inclination angle of pelvis	−.81	−.18	−.18	.34	−.06
K44	Incl. angle of lumbo-pubic depth	−.90	.06	.19	−.03	.23
36	Sacral inclination angle	.59	−.40	−.28	.06	−.44
W	α-angle (between pub. and ilium)	.11	−.86	−.43	−.05	.11
W	β-angle (between pub. and isch.)	−.36	−.31	.77	.12	.15
W	γ-angle (between ilium and isch.)	.14	.94	−.15	−.04	−.19

[1)] The sample size is 16. The cumulative proportion of the variances of the five principal components is 84.96%.
[2)] See the second footnote to Table 1.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed bootstrap test.

Table 18. 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 sets of neurocranial and pelvic measurements.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.85***	—	—	—	—	—	—	—	—	.57*
II	—	—	.63*	—	—	—	—	.65**	—	—
III	—	—	—	—	—	—	—	—	—	—
IV	—	.85***	—	—	—	.64*	.67**	—	—	.53*
V	—	—	—	—	—	—	—	—	—	—
Fac I	.82***	—	—	—	—	—	—	—	—	—
II	—	—	—	—	—	—	—	—	—	—
III	—	—	.63*	—	—	—	.55*	.58*	—	—
IV	—	—	—	—	—	—	—	—	—	—
V	—	—	.63*	—	—	—	—	—	—	.60*

[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 2, 3, 4 and 5.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed test.

Table 19. 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 sets of neurocranial and pelvic measurements.[1)]

	Male PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC I	.89***	.58*	—	—	—	.78***	.52*	—	—	—
II	—	.81***	—	—	—	.57*	.66**	—	—	.67**
III	—	—	—	.66**	—	—	—	—	.51*	—
IV	—	—	—	—	—	—	—	—	—	—
Fac I	.66**	.58*	—	—	—	.64**	—	—	.63**	—
II	—	.79***	—	—	—	—	.70**	—	—	.85***
III	—	—	.55*	—	—	—	.53*	.60*	—	—
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 6, 7, 8 and 9.
* $P<0.05$; ** $P<0.01$; *** $P<0.001$, by a two-tailed test.

most highly correlated with cranial length among the rotated factors extracted there, had relatively high correlations with mandibular length and iliac breadth. Although the statistical significance of the results was not tested at that time, the close connection was confirmed in the present study through the significance tests of the results from both male and female data.

Further, Mizoguchi (1992) applied PCA to the correlation matrix on somatometric data of Japanese males reported by Hoshi and Kouchi (1978), and showed that there was a relatively strong association between head length and bicristal breadth. Again in this case, the statistical significance was not tested. But the result is not inconsistent with the present findings.

The present and the above findings by Mizoguchi are also compatible with Mizoguchi's (1998b) results that cranial length is strongly associated with the sacral breadths at the upper and middle levels.

Both in obstetrics and in anthropology, it has been pointed out that the shapes of the fetal head and the maternal pelvic inlet play important roles when the fetus successfully negotiates the birth canal (Rosenberg, 1992; Rosenberg and Trevathan, 1996; Abitbol, 1993). Namely, in modern humans, the longest axis of the fetal head lies in

Table 20. 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 third sets of neurocranial and pelvic measurements.[1)]

	Male	PC I	II	III	IV	V	Fac I	II	III	IV	V
Female PC	I	.83***	—	—	—	—	.76***	—	—	—	—
	II	.58*	—	—	—	—	—	—	—	—	—
	III	—	—	—	—	—	—	.71**	—	—	—
	IV	—	—	—	—	—	—	—	—	.60*	—
	V	—	—	.56*	.59*	—	.61*	—	—	—	—
Fac	I	.76***	—	—	.51*	—	.94***	.50*	—	—	—
	II	.54*	—	—	—	—	—	—	—	—	—
	III	—	—	—	—	—	—	—	—	—	—
	IV	—	—	—	—	—	—	.52*	—	—	—
	V	—	.66**	—	—	—	—	.63**	—	—	—

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 10, 11, 12 and 13.

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

Table 21. 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 fourth sets of neurocranial and pelvic measurements.[1)]

	Male	PC I	II	III	IV	V	VI	Fac I	II	III	IV	V	VI
Female PC	I	.56*	—	—	—	—	—	—	—	—	—	—	—
	II	—	.55*	—	—	—	—	—	—	—	—	—	—
	III	—	—	—	—	—	.60*	—	—	—	—	—	—
	IV	—	—	—	—	—	—	—	—	—	.61*	—	—
	V	—	—	—	—	—	—	—	—	—	—	—	—
Fac	I	.57*	—	—	—	—	—	—	—	—	—	—	—
	II	—	—	—	—	—	—	—	—	—	.54*	—	—
	III	—	—	—	—	—	.60*	—	—	—	.54*	—	—
	IV	—	—	—	—	—	—	—	—	—	—	.54*	—
	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 14, 15, 16 and 17.

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

the sagittal direction and that of the maternal pelvic inlet exists in the transverse direction. Therefore, when the fetal head enters the maternal pelvic inlet, its sagittal axis is aligned with the maternal transverse axis. From this fact, it is expected that there is a high correlation between the fetal head and the maternal pelvic dimensions.

The above findings by the present author, however, are based on the data from the same adult individuals, not from fetuses and their mothers. Nevertheless, strong associations were found between the neurocranium and the pelvis. How should this be interpreted?

The shape of the fetal neurocranium must be determined by both maternal and paternal genes. But, independent of whether they derive from its mother or father, those genes which produce such a cranial shape as does not fit the shape of its mother's pelvis are weeded out. Namely, the cranial shapes of all living newborns must be within the variation of the shapes of mothers' pelves. On the other hand, those mothers whose pelvic shape does not fit a possible shape of the fetal neurocranium cannot have children, and the genes generating such a pelvic shape must be excluded from the gene pool of the population. In other words, apart from the genes concerned with the sexual dimorphism of the pelvis, even boys, as long as they are alive, must also carry the genes that express the same general pelvic shapes as their mothers' appropriate ones.

After all, as was suggested by Mizoguchi (1998b), it is most likely that the shapes of the neurocranium and pelvis have been formed, mutually affecting each other, through the human evolutionary process. Hence, in the modern human population, the close correspondence between the neurocranial and the pelvic forms is fixed as a population characteristic.

Among-population variations

The above-stated analyses are based on within-population variations, not on among-population variations. But brachycephalization is a phenomenon between a series of populations of different periods in a certain region, in other words, an among-population phenomenon. Here, therefore, some previous analyses of among-population variations in cranial and pelvic measurements are reviewed.

Facchini and Gualdi-Russo (1982) showed the data on secular changes of some anthropometric variables in Bologna, Italy. According to their tables, maximum head length and bicristal breadth seem to have changed in parallel from 1930 to 1982 both in males and in females (Table 22). This is not inconsistent with the results of the analyses of within-population variations mentioned above.

Kurisu (1970) reported somatometric data on the male samples from eight native groups in Sarawak, Malaysia. On the basis of the mean values, the present author calculated Spearman's rank correlation coefficients between head and body measurements (Table 23). As a result, it was found that biiliac breadth was highly significantly associated with head length (Spearman's rho$=$0.86; $P<0.01$). This is again compatible with the results of the present and previous analyses based on within-population variations.

Brachycephalization and the pelvic shape

The above-mentioned studies based on both within-population and among-population variations suggest that pelvic breadth is strongly associated with cranial length. If so, one of the causes for brachycephalization may have been a secular change in the form of female pelves. But, if it is the case, what did make the pelvic shape change? That may have been a secular change in the way of walking? Regarding this, much more detailed analyses should be conducted in the future.

Summary and Conclusions

The principal component analyses and the rotation of their results on the neurocranium and the pelvis revealed that cranial length and pelvic breadth were strongly associated with each other. It is inferred from these findings and previous studies based on both within-population and among-population variations that the form of the maternal pelvic inlet has played and still plays an

Table 22. Secular changes of cranial and pelvic measurements in Bologna, Italy.[1)]

		Year of report: 1930			1941			1982		
		Mean	(*n*)	SD	Mean	(*n*)	SD	Mean	(*n*)	SD
Maximum head length	Male	188	(300)	—		—		190.0	(267)	6.8
	Female	183	(300)	—	178	(50)	7.0	180.7	(219)	6.1
Maximum head breadth	Male	158	(300)	—		—		149.1	(267)	6.6
	Female	153	(300)	—	147	(50)	7.0	142.4	(219)	6.3
Bicristal breadth	Male	296	(300)	17		—		328.6	(265)	28.6
	Female	298	(300)	—	273	(50)	20	314.5	(219)	31.4

1) Data source: Facchini and Gualdi-Russo (1982).

Table 23. Spearman's rank correlation coefficients between head and body measurements based on the means in male samples from eight native groups in Sarawak, Malaysia.[1)]

	Head length	Head breadth	Length-breadth index
Head breadth	−.62	—	—
Length-breadth index	−.74*	.95***	—
Auricular height	.00	.00	.10
Bizygomatic breadth	.26	.02	.12
Bigonial breadth	.74*	−.14	−.29
Physiognomic facial height	.02	.06	−.07
Morphological facial height (g-gn)	−.50	.74*	.67
Nose height (g-sn)	−.02	.50	.57
Nose breadth	.31	−.26	−.12
Stature	.12	.36	.38
Trunk length	−.21	.55	.55
Arm length	−.31	.67	.67
Leg length	.69	−.57	−.57
Biacromial breadth	.57	−.02	−.17
Biiliac breadth	.86**	−.81*	−.90**

[1)] Data source: Kurisu (1970).
* $P<0.05$; ** $P<0.01$; *** $P<0.001$.

important role in determining the neurocranial form in modern human populations, and that one of the causes for brachycephalization may have been a secular change of the pelvic form.

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