Change in facial shape in two cohorts of Japanese adult female students twenty years apart

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ABSTRACT

Introduction: Secular changes in the head and body dimensions of the Japanese population were recorded during the last century, but studies on Japanese adult facial shape were poorly documented. This study aimed to document the secular changes in facial shape and their association with craniofacial measures of Japanese adult female students.

Methods: Data were collected from 1998–2001 and 1975–1979 from institutions in Tokyo and Kyoto. The prosopic index (PI) was derived from morphological facial height (n-gn) and bizygomatic breadth (zy-zy). Multiple regression analysis was used to determine the association between PI (facial form) and craniofacial measures.

Results: Larger mean values for morphological facial height (n-gn) and for PI, but smaller values for bizygomatic breadth (zy-zy) and bigonial breadth (go-go) were observed in the current sample compared to their predecessors 21 years ago. The most prevalent facial shapes were mesoprosopic (30.53 percent) and euryprosopic (45.14 percent) for the current and previous series, respectively. There was a significant positive relationship between the PI and head length (g-op) (p less than 0.01), head breadth (eu-eu) (p less than 0.01) and head height (v-po) (p less than 0.05), and a negative relationship between the PI and head circumference (g-g) (p less than 0.01) and minimum frontal breadth (ft-ft) (p less than 0.01).

Conclusion: Our results suggest that a narrowing of facial shape has been occurring for approximately 21 years in adult Japanese females. The best predictor variables for PI were head length, head circumference, head breadth, minimum frontal breadth and head height.

Keywords: craniofacial measures, facial shape, Japanese females, multiple regressions, proscopic index

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INTRODUCTION

The human facial contour has always been an interesting subject for artists and plastic surgeons.[1] From the human facial form, it is possible to make an absolute distinction between two ethnic groups.[2,3] Craniofacial morphometrics is an important component of physical anthropometrics, which include the head and face dimensions. The results obtained from such craniofacial studies are used in forensic medicine, plastic surgery, oral surgery, paediatrics, dentistry, and for diagnostic comparisons between patients and normal populations.[4]

In Japan, Suzuki was one of the early researchers who described the craniofacial morphology of Japanese adults.[5] According to Suzuki, the protohistoric Japanese population was long-headed, with a broad face and strong prognathism. Craniofacial morphology is commonly described by the head (cephalic index) and face form (prosopic index).[5] Progressive brachycephalisation of the head form has been noted since the medieval Kamakura era, and the rate of increase in the cephalic index of Japanese adults over the last hundred years has been extremely high, as reported by numerous researchers.[6-12] On the other hand, there were very few reports on the changes in facial form of Japanese adults over time, and this is probably due to large inter-observer measurement errors in the few existing somatometric data sets.[13] Prosopic index (PI) is a measurement of facial form based on the ratio of morphological facial height (n-gn) and bizygomatic breadth (zy-zy). The impact of craniofacial measurements on the PI is not well documented.

The purpose of the current study was to find the secular changes in craniofacial morphology based on the PI of Japanese adult female students over two decades,

Table I. Anthropometric landmarks used for measuring craniofacial measurements.

Measurement (mm)	Landmarks	
	Beginning	End
Head length (g-op)	Glabella (g)	Opisthocranion (op)
Head breadth (eu-eu)	Left eurion (eu)	Right eurion (eu)
Head height (v-po)	Vertex (v)	Porion (po)
Head circumference (g-g)(cm)	Glabella (g)	Glabella (g)
Minimum frontal breadth (ft-ft)	Left frontotemporale (ft)	Right frontotemporale (ft)
Bizygomatic breadth (zy-zy)	Left zygion (zy)	Right zygion (zy)
Bigonial breadth (go-go)	Left gonion (go)	Right gonion (go)
Morphological facial height (n-gn)	Nasion (n)	Gnathion (gn)

Note: All measurements are in mm unless otherwise stated.

and to identify specific parameters that influence the index (PI).

METHODS

The sample population of the current study consisted of 832 healthy Japanese adult female students from several universities in the Tokyo and Kyoto areas. The measurements were conducted between 1998 and 2001. Various districts of Japan were represented. The age of the students at the time of measurement was 18–25 years old, with an average age of 19.32 ± 0.95 years. The following eight craniofacial parameters were measured by a single observer, Fumio Ohtsuki (FO): head length (g-op); head breadth (eu-eu); head height (v-po); head circumference (g-g); minimum frontal breadth (ft-ft); bigonial breadth (go-go); bizygomatic breadth (zy-zy); and morphological facial height (n-gn). The anthropometric landmarks used for measuring craniofacial measurements are described in Table I. In addition, stature (St) and body weight (Wt) were measured. Measurements were taken following the technique of Martin and Saller.[14] Utilising two of the facial variables, the PI was calculated using equation [1]:

$$\mathrm{PI} = \frac{\textit{morphological facial height (n–gn)}}{\textit{bizygomatic breadth (zy–zy)}} \times 100 \quad [1]$$

A previous data set collected by FO was available for comparative purposes. He had taken the head and facial measurements as well as height and weight of Japanese adult female students from various colleges and universities in the Tokyo area from 1975 to 1979, using the same technique of Martin and Saller.[14] The data series consisted of 1,547 healthy Japanese female students aged 18–25 years. Head and body dimensions from the data series were used in the study of Ohtsuki and Ito.[8] This data set was collected approximately 21 years prior to the current series.

The two data sets (current and previous) were checked for outliers using the techniques suggested by Dunn and Clark,[15] since they can affect the interpretation of the results.[16] Some outliers and missing values were identified and excluded in the previous data set, and the number of subjects was reduced from 1,547 to 1,491.

Table II. Types of facial forms according to prosopic index (PI).

PI value	Description	Type of form
PI ≤ 79.9	Hypereuryprosopic	Very broad face
80 ≤ PI ≤ 84.9	Euryprosopic	Broad face
85 ≤ PI ≤ 89.9	Mesoprosopic	Round face
90 ≤ PI ≤ 94.9	Leptoprosopic	Long face
PI ≥ 95	Hyperleptoprosopic	Very long face

Utilising Banister's classification, the PI for both data sets was divided into six categories (Table II).[17] Descriptive statistics were calculated for the following five variables: minimum frontal breadth (ft-ft); bigonial breadth (go-go); bizygomatic breadth (zy-zy); morphological facial height (n-gn); and PI. Comparisons were then made between the current and previous series. Multiple regression analysis was used to find the average relationship between the PI and the craniofacial measurements. The underlying multiple linear regression model corresponding to each variable was as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_k X_k + \varepsilon \quad [2]$$

where Y is the response (dependent) variable (PI), X_i (i = 1, 2, 3,…, k) are the predictor variables (craniofacial measurements), β_0 is the intercept term, β_1, β_2,…, β_k are the unknown regression coefficients, and ε is the error term with a $N(0, \sigma^2)$ distribution.

An important assumption of the multiple regression analysis is that the explanatory variables are independent of each other, i.e. there is no relationship between the explanatory variables to estimate the ordinary least squares. However, in some applications of regression, the explanatory variables are related to each other. This is called the multicollinearity problem. In this study, a variance inflation factor (VIF) was used to check for the

Table III. Comparison of mean values of the eight craniofacial measurements with the prosopic index in Japanese adult females between the two time periods.

Variable	Mean ± SD		Difference (%) (A−B)	Type of changes
	Current series (A) (n = 832)	Previous series (B) (n = 1,491)		
Head length (g-op) (mm)	180.12 ± 6.83	179.07 ± 5.90	1.05* (0.59)	Mild
Head breadth (eu-eu) (mm)	154.62 ± 5.53	155.00 ± 5.53	−0.38 (0.25)	Mild
Head height (v-po) (mm)	129.56 ± 6.20	122.83 ± 6.87	6.73* (5.19)	Mild
Head circumference (g-g) (cm)	55.23 ± 1.44	55.12 ± 1.31	0.02 (0.04)	Mild
Minimum frontal breadth (ft-ft) (mm)	123.15 ± 6.19	123.39 ± 5.8	−0.24 (0.19)	Mild
Bizygomatic breadth (zy-zy) (mm)	138.49 ± 5.06	138.70 ± 4.45	−0.21 (0.15)	Mild
Bigonial breadth (go-go) (mm)	94.93 ± 8.50	105.65 ± 4.98	−10.72* (11.29)	Moderate
Morphological facial height (n-gn) (mm)	114.40 ± 10.54	111.64 ± 4.77	2.76* (2.41)	Mild
Prosopic index	82.66 ± 7.67	80.55 ± 3.81	2.11* (2.55)	Mild

* denotes 5% level of significance.

Table IV. Distribution of facial shape based on the prosopic index (PI) in Japanese adult females.

PI value	Frequency (%)	
	Present series (A) (n = 832)	Previous series (B) (n = 1,491)
Hypereuryprosopic (PI ≤ 79.9)	240 (28.85)	638 (42.79)
Euryprosopic (80 ≤ PI ≤ 84.9)	208 (25.00)	673 (45.14)
Mesoprosopic (85 ≤ PI ≤ 89.9)	254 (30.53)	163 (10.93)
Leptoprosopic (90 ≤ PI ≤ 94.9)	105 (12.62)	10 (0.67)
Hyperleptoprosopic (PI ≥ 95)	25 (3.00)	7 (0.47)

Table V. Multiple regression coefficients and the variance inflation factor (VIF) for the measurements, with the prosopic index as the response variable.

Predictor	Coefficient	VIF
Head length (g-op)	0.58407**	2.7
Head breadth (eu-eu)	0.30722**	2.0
Minimum frontal breadth (ft-ft)	−0.18639**	1.5
Head height (v-po)	0.08121*	1.2
Bigonial breadth (go-go)	−0.02739	1.1
Head circumference (g-g)	−2.1153**	4.1
Stature (cm)	0.04226	1.3
Body weight (kg)	0.02960	1.7

* denotes 5% level of significance.
** denotes 1% level of significance.

multicollinearity problem among the predictor variables. The variance inflation for independent variables Xj is:

$$VIFj = 1/(1-R^2j), j = 1, 2,\ldots, p \quad [3]$$

where p is the number of predictor variables and R^2 j is the square of the multiple correlation coefficient of the jth variable with the remaining (p – 1) variables where: (a) if $0 < VIF < 5$, there is no evidence of multicollinearity problem; (b) if $5 \leq VIF \leq 10$, there is a moderate multicollinearity problem; and (c) if $VIF > 10$, there is seriously multicollinearity problem of variables.[18]

Finally, stepwise regression, a technique for selecting influential variables in multiple regression models,[18] was utilsed in order to select the most influential craniofacial measures for PI. Since PI was derived from bizygomatic breadth (zy-zy) and morphological facial height (n-gn), these two variables were excluded from both multiple and stepwise regression analyses. Statistical analyses were carried out using the Statistical Package for the Social Sciences software version 15 (SPSS, Chicago, IL, USA).

RESULTS

Based on the available data sets, we were able to demonstrate a weak trend in decreasing minimum frontal breadth (ft-ft) and bizygomatic breadth (zy-zy), but a strong trend in decreasing bigonial breadth (go-go) over the period from 1975 to 2001 (Table III). Mean values of morphological facial height (n-gn) and morphological facial index (PI) showed a strong increasing trend (Table III). The difference in mean minimum frontal breadth (ft-ft) and bizygomatic breadth (zy-zy) between the current and previous series was –0.24 mm and –0.21 mm, respectively, which were statistically insignificant. However, the difference in bigonial breadth (go-go) between the current and previous series (–10.72 mm) was statistically significant ($p < 0.01$). The morphological facial height (n-gn) of the current series was larger by 2.76 mm compared to that of the previous series, and this was also statistically significant ($p < 0.01$). The mean PI increased by 2.11 units ($p < 0.01$) during the last two decades among Japanese adult females (Table III).

Table VI. Comparison of mean values of the eight craniofacial measurements with the prosopic index (PI) in Japanese adult females between the two time periods.

	Coefficient				
	Step 1	Step 2	Step 3	Step 4	Step 5
Head length (g-op)	0.289**	0.482**	0.589**	0.584**	0.588**
Head circumference (g-g)		−1.310**	−2.070**	−1.910**	−2.070**
Head breadth (eu-eu)			0.214**	0.307**	0.304**
Minimum frontal breadth (ft-ft)				−0.189**	−0.179**
Head height (v-po)					0.085*
No. of variable	1	2	3	4	5
R-square (%)	6.65	9.73	11.08	12.69	13.10
R-square (adj) (%)	6.54	9.51	10.76	12.27	12.57
Mallows Cp	57.7	30.8	20.0	6.9	5.0

* denotes 5% level of significance.
** denotes 1% level of significance.

The dominant type of facial shape of Japanese females in the current and previous series was mesoprosopic (30.53%) and euryprosopic (45.14%), respectively (Table IV). The percentages of mesoprosopic, leptoprosopic and hyperleptoprosopic facial shape types were higher in the current series than in the previous series, while those of hypereuryprosopic and euryprosopic facial shape types were higher in the previous series. These results indicated that a secular change toward a narrower and higher facial size in Japanese females has been occurring over the last two decades.

The multiple regression model used is shown as equation [4], where PI is a response variable and other variables are predictors:

$$PI = \beta_0 + \beta_1(g\text{-}op) + \beta_2(eu\text{-}eu) + \beta_3(ft\text{-}ft) + \beta_4(go\text{-}go) + \beta_5(v\text{-}po) + \beta_6(g\text{-}g) + \beta_7 St + \beta_8 Wt + \epsilon \quad [4]$$

NB: St: stature (cm), Wt: body weight (kg)

The estimated model is shown as equation [5]:

$$PI\hat{} = 53.60 + 0.584(g\text{-}op) + 0.307(eu\text{-}eu) - 0.186(ft\text{-}ft) - 0.0274(go\text{-}go) + 0.0812(v\text{-}po) - 2.12(g\text{-}g) + 0.0423 St + 0.0296\ Wt \quad [5]$$

NB: St: stature (cm), Wt: body weight (kg)

The regression coefficients and the VIF of the independent variables are presented in Table V. The VIF showed that there was no evidence of a multicollinearity problem among the predictor variables. The coefficient of the regression line showed a significant positive association between the PI and head length (g-op) ($p < 0.01$) and between head breadth (eu-eu) ($p < 0.01$) and head height (v-po) ($p < 0.05$), while a negative relationship was found between the PI and minimum frontal breadth (ft-ft) ($p < 0.01$) and head circumference (g-g) ($p < 0.01$). These results suggest that individuals with larger head length (g-op), head breadth (eu-eu) and head height (v-po), and shorter minimum frontal breadth (ft-ft) and head circumference (g-g) were associated with a narrower and higher facial shape.

The stepwise regression analysis showed that head length (g-op) was included in the first step (Table VI). The R^2 value indicated that there was a 6.65% reduction in the total variation of the PI due to the predictor variable of head length (g-op). The second step included both the head length (g-op) and head circumference (g-g). The R^2 value now indicated a 9.73% reduction in the total variation of the PI due to these two predictor variables. The third step included the head length (g-op), head circumference (g-g) and head breadth (eu-eu), with the R^2 value indicating a 11.08% reduction in the total variation in the PI due to these three variables. The fourth step included the head length (g-op), head circumference (g-g), head breadth (eu-eu) and minimum frontal breadth (ft-ft), with an R^2 demonstrating a 12.69% reduction in the total variation of the PI due to these four variables. The final step included the head length (g-op), head circumference (g-g), head breadth (eu-eu), minimum frontal breadth (ft-ft) and head height (v-po), with an R^2 value that led to a 13.10% reduction in the total variation of the PI. The value of Mallows' Cp decreased with each increment, and the smallest value (5.0) was found in the final step. These results demonstrated that the important craniofacial factors that influenced the PI were head length (g-op), head circumference (g-g), head breadth (eu-eu), minimum frontal breadth (ft-ft) and head height (v-po).

DISCUSSION

A comparison of the two different series in facial measurements showed that secular changes in the facial shape of Japanese adult females have been occurring over the last two decades. In terms of the face dimensions, morphological facial height (n-gn) increased substantially, while bizygomatic breadth (zy-zy) decreased slightly (Table III) over this period. As expected, these changes were also reflected in the PI. The total change in the PI was 2.11 units, equivalent to an incremental change of 0.1 units per year. These findings suggest a tendency toward a narrower face in Japanese adult females, which are supported by the earlier findings of Suzuki, who reported that during the Jomon (13,000–300 BC) period, Japanese people had a broader face than during the Kofun (250–538 AD) period, whereas modern (the early 20th century) Japanese people had even higher and narrower faces than the people from the Kofun age.[19,20] The current observations are also in agreement with the findings of Jantz et al, which showed a narrowing trend of facial form in the Americans during their investigating period.[21] Our results also concur with those of Gyenis' study on facial dimensions of university female students in Hungary, in which the author showed that the facial form has became narrower during the study period (1976–1985).[22] However, the current findings are limited to female data. Previous studies demonstrated that both males and females showed the same tendency of brachycephalisation/debrachycephalisation in Japan over time.[11,12,23] Moreover, as far as we know, there are no comparable studies on secular changes over time available for facial dimensions of Japanese adult males.

Multiple regression and stepwise regression analyses were used in the present study to identify important craniofacial measurements that influence the facial form of Japanese adult female students. These statistical analyses demonstrated that most of the head measurements and minimum frontal breadth (ft-ft) were important factors influencing the PI. The coefficients of the regression line verified that there was a positive relationship between the PI and head length (g-op), head breadth (eu-eu) and head height (v-po), and a negative relationship between the PI and head circumference (g-g) and minimum frontal breadth (ft-ft). As mentioned earlier, the head length (g-op) and head breadth (eu-eu) were excluded from the analysis, but bizygomatic breadth (zy-zy) and morphological facial height (n-gn) were separately analysed. Positive association between the PI and morphological facial height (n-gn) (coefficient, $\beta = 0.922$ and $p < 0.01$) was found, while the PI was negatively associated with bizygomatic breadth (zy-zy) (coefficient $\beta = -0.18$ and $p < 0.01$). To the best of our knowledge, there are no comparable studies available that document the relationship between the PI and craniofacial measurements; consequently, these findings cannot be compared to other studies.

The present study showed that the face of average Japanese female adults is narrower (rounded) and higher, and this is mainly a result of the increase of morphological facial height (n-gn), decrease in bizygomatic breadth (zy-zy) and minimum frontal breadth (ft-ft). It is not clear what is responsible for the changes in human facial form over time.[24] Many hypotheses have been proposed for secular changes, such as environmental factors,[25] an increase in dietary protein, a decrease in psychological and physiological stress, improved medical facilities and care, changes in the living environment, development of interregional communication and transportation system[26] as well as changes in the climate.[27,28] Some researchers believe that these changes have been selected by nature.[29,30] Clearly, more research will be required to provide a more definitive answer.

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