Consistency of Nonmetric Cranial Trait Expression during the Last 2,000 Years in the Habitants of the Central Islands of Japan

Yukio DODO and Hajime ISHIDA

Department of Anatomy, Sapporo Medical College

Abstract Incidences of 22 nonmetric cranial traits were compared through uni- and multi-variate procedures between seven cranial series from the central islands of Japan covering the past 4,000 years of Japanese population history. The results indicated that there is a clear difference in the incidence of nonmetric traits between the native Jomon and the immigrant Yayoi, but thereafter, the incidence has remained stable over the 2,000 years from the Yayoi period to the present time. Taken these together, it is inferred that the northern Kyushu Yayoi of continental lineage must be one of the lineal forerunners of the modern Japanese of the central islands of Japan.

Key Words Nonmetric trait, Skull, Incidence pattern, Yayoi people, Japanese

Introduction

Our recent studies on nonmetric cranial trait variations in Japanese islanders have revealed the following. (1) Most of the nonmetric traits of our battery show a remarkable homogeneity in frequency during the last 600 years from the early medieval to the present time in Honshu, the main island of Japan, a period during which reliable documentation shows no significant gene inflow from overseas into this region. (2) The trait-incidence pattern of the Jomon is quite distinct from those of the protohistoric and historic Japanese in Honshu. (3) In respect to nonmetric trait expressions, the Yayoi of northern Kyushu as represented by the Kanenokuma are far closer to the protohistoric and historic Japanese in Honshu than are the Doigahama Yayoi of Yamaguchi Prefecture, the westernmost part of Honshu (DODO and ISHIDA, 1990; DODO et al., 1992). Our interest is now focused on the Yayoi subsisting in northern Kyushu around 2,000 years ago, because, in terms of nonmetric cranial variation, they are considered a probable lineal ascendant of the present-day inhabitants of the greater part of Japan (DODO et al., 1992). In this study, a secular trend in the incidence pattern of nonmetric cranial traits is examined using seven cranial series covering the past 4,000 years of Japanese population history in order to confirm the post-Jomon stability of these traits in the central islands of Japan.

Materials and Methods

Seven cranial series from the central islands of Japan (six from Honshu and one from Kyushu), ranging in age from around 4,000 years ago to the present time, were investigated for the presence or absence of 22 nonmetric traits. Table 1 shows the sample sizes, provenances and approximate ages of these materials. All the
Table 1. List of materials

| Cranial series          | Number of skulls | Provenance               | Approximate age*         |
|-------------------------|------------------|--------------------------|--------------------------|
| Jomon                   | 171              | Central and Eastern Honshu| 2,000BC ~ 300BC          |
| Yayoi                   | 191              | Northern Kyushu          | 100BC ~ 100AD            |
| Protohistoric Kofun     | 276              | Central and Eastern Honshu| 500AD ~ 800AD            |
| Early Medieval Kamakura | 220              | Central Honshu           | 1,300AD ~ 1,350AD        |
| Late Medieval Muromachi | 124              | Central Honshu           | 1,400AD ~ 1,550AD        |
| Early Modern Edo        | 194              | Central Honshu           | 1,650AD ~ 1,800AD        |
| Modern                  | 180              | Central and Eastern Honshu| 1,850AD ~ 1,930AD        |

*Ages were estimated consulting WATANABE (1966), NAKAHASHI and NAGAI (1989), and SUZUKI (1963)

materials listed in this table are the same as described in DODO et al. (1992). The Yayoi crania from northern Kyushu, one third of which were recovered at the Kanenokuma site in Fukuoka City, are generally believed to represent continental immigrants and their offspring.

The 22 traits shown in Table 2 were scored as present or absent for each individual cranium by the senior author (Y.D.) according to the criteria described in previous reports (DODO, 1974, 1975, 1986). For both bilateral and median traits, incidence was determined using the skull (i.e., either or both sides); sex was not taken into account. FISHER’s exact probability test was used to evaluate the significance of difference in trait-incidence between the two samples compared. In order to assess biological distances between samples, C.A.B. SMITH’s Mean Measure of Divergence (MMD) and its standard deviation (SD) were computed using the formulae recommended by SJOVOLD (1973). Principal coordinate analysis (SNEATH and SOKAL, 1973) was performed on the MMD matrix to graphically represent mutual relationships of cranial samples.

**Results**

**Univariate comparison**

Skull-incidences of the 22 traits in the seven cranial series are given in Table 2. The difference in incidence of each trait was tested by FISHER’s exact probability test between Jomon-Yayoi, Yayoi-Kofun, Kofun-Kamakura, Kamakura-Muromachi, Muromachi-Edo, and Edo-Modern. Statistically significant differences in each couple of cranial series are marked also in Table 2.

Comparison of the Jomon and Yayoi samples yielded the highest number of disparities. These were noted for the differences at the supraorbital foramen, biasterionic suture vestige, hypoglossal canal bridging, medial palatine canal and transverse zygomatic suture vestige at the level of 0.001. Differences at the metopism and mylohyoid bridging showed the level of 0.01 and those at the patent condylar canal and foramen of VESALIUS at the level of 0.05. A total of 9 traits showed a significant difference at the 0.05 level or less.

On the other hand, comparisons between the six post-Jomon cranial series showed significant differences in only five instances – the ossicle at lambda between the Edo and Modern (0.05 level); the biasterionic suture vestige between the Yayoi and Kofun (0.05 level); the parietal notch bone between the Edo and Modern (0.01 level); the tympanic dehiscence between the Kamakura and Muromachi, and between the Muromachi and Edo (0.05 level).

To be brief, 40.9 percent of all the paired incidences (9/22) showed significant differences at the 0.05 level between the Jomon and Yayoi, whereas only 4.5 percent of them (5/110) between the six post-Jomon cranial series. The difference
Table 2. FISHER’s exact probability test for the difference in trait-incidence in each couple of contiguous cranial series (trait-incidence is based on skull and pooled-sex sample)

| Traits                        | Jomon (%) | Yayoi (%) | Kofun (%) | Kamakura (%) | Muromachi (%) | Edo (%) | Modern (%) |
|-------------------------------|-----------|-----------|-----------|--------------|---------------|---------|------------|
| 1. Metopism                   | 24/159 (15.1) | 9/185 (4.9) | 5/199 (2.5) | 9/204 (4.4) | 8/124 (6.5) | 10/194 (5.2) | 16/180 (8.9) |
| 2. Supraorbital nerve groove  | 20/117 (17.1) | 19/151 (12.6) | 22/107 (20.6) | 24/175 (13.7) | 19/102 (18.6) | 48/177 (27.1) | 55/177 (31.1) |
| 3. Supraorbital foramen       | 23/124 (18.5) | 84/174 (48.3) | 75/134 (56.0) | 99/185 (53.5) | 63/116 (54.3) | 101/184 (54.9) | 99/180 (55.0) |
| 4. Ossicle at lambda          | 7/156 (4.5) | 11/141 (7.8) | 17/164 (10.4) | 16/188 (8.5) | 9/121 (7.4) | 19/188 (10.1) | 7/174 (4.0) |
| 5. Biasterionic suture vestige| 52/138 (37.7) | 4/94 (4.3) | 18/146 (12.3) | 21/185 (11.4) | 12/121 (9.9) | 30/192 (15.6) | 28/176 (15.9) |
| 6. Asteric bone               | 16/113 (14.2) | 8/72 (11.1) | 15/111 (13.5) | 29/169 (17.2) | 15/104 (14.4) | 18/146 (12.3) | 20/172 (11.6) |
| 7. Occipitomastoïd bone       | 11/66 (16.7) | 9/58 (15.5) | 17/86 (19.8) | 25/127 (19.7) | 19/81 (23.5) | 22/146 (15.1) | 31/179 (17.3) |
| 8. Parietal notch bone        | 18/88 (20.5) | 26/88 (29.5) | 18/95 (18.9) | 37/164 (22.6) | 24/99 (24.2) | 38/160 (23.8) | 62/172 (36.0) |
| 9. Patent condylar canal      | 42/142 (100.0) | 68/76 (89.5) | 83/90 (92.2) | 83/91 (91.2) | 64/77 (83.1) | 119/148 (80.4) | 153/178 (86.0) |
| 10. Precondylar tubercle      | 8/80 (10.0) | 10/122 (8.2) | 10/116 (8.6) | 5/111 (4.5) | 3/85 (3.5) | 10/154 (6.5) | 16/178 (9.0) |
| 11. Paracondylar process      | 2/15 (13.3) | 0/44 (0.0) | 1/52 (1.9) | 1/41 (2.4) | 1/65 (1.5) | 4/114 (3.5) | 9/168 (5.4) |
| 12. Hypoglossal canal bridging| 28/84 (33.3) | 17/130 (13.1) | 22/130 (16.9) | 19/128 (14.8) | 13/88 (14.8) | 26/155 (16.8) | 26/180 (14.4) |
| 13. Tympanic dehiscence       | 43/127 (33.9) | 55/137 (40.1) | 60/143 (42.0) | 65/191 (34.0) | 46/102 (45.1) | 56/166 (33.7) | 64/179 (35.8) |
| 14. Ovale-spinous confluenq   | 2/44 (4.5) | 4/135 (3.0) | 2/104 (1.9) | 6/130 (4.6) | 1/87 (1.1) | 2/151 (1.3) | 3/180 (1.7) |
| 15. Foramen of VESALIUS       | 31/55 (56.4) | 61/147 (41.5) | 49/103 (47.6) | 52/114 (45.6) | 44/82 (53.7) | 68/150 (45.5) | 84/179 (46.9) |
| 16. Pterygospinous foramen    | 3/65 (4.6) | 2/152 (1.3) | 3/112 (2.7) | 2/158 (1.3) | 2/91 (2.2) | 9/151 (6.0) | 5/179 (2.8) |
| 17. Medial palatine canal     | 15/80 (18.8) | 6/162 (3.7) | 9/124 (7.3) | 9/149 (6.0) | 2/83 (2.4) | 9/129 (7.0) | 14/177 (7.9) |
| 18. Transverse zygomatic suture vestige | 31/68 (45.6) | 8/64 (12.5) | 7/35 (20.0) | 8/90 (8.9) | 5/57 (8.8) | 13/95 (13.7) | 19/167 (11.4) |
| 19. Clinoid bridging          | 0/10 (0.0) | 4/102 (3.9) | 2/82 (2.4) | 2/51 (3.9) | 4/59 (6.8) | 7/131 (5.3) | 8/177 (4.5) |
| 20. Mylohyoid bridging        | 23/112 (20.5) | 4/73 (5.5) | 5/77 (6.5) | 2/51 (3.9) | 4/40 (10.0) | 3/131 (2.3) | 11/177 (6.2) |
| 21. Jugular foramen bridging  | 1/34 (2.9) | 11/98 (11.2) | 5/84 (6.0) | 8/83 (9.6) | 12/75 (16.0) | 21/188 (11.2) | 27/222 (12.2) |
| 22. Sagittal sinus groove turns left | 15/127 (11.8) | 20/126 (15.9) | 24/184 (13.0) | 24/159 (15.1) | 21/113 (18.6) | 23/175 (13.1) | 26/153 (17.0) |

Note: >> >> >> > > : significant at the levels of 0.001, 0.01, and 0.05, respectively.
is highly significant ($p = 0.000024$).

**Multivariate analysis**

SMITH's MMD and its standard deviation were computed for each couple of the seven cranial series on the basis of the incidence data of the 22 traits. The results are given in Table 3. When a MMD was twice as large as its standard deviation or more, it was judged to be significant at the 0.05 level (Sjøvold, 1973). As seen in Table 3, the MMDs between Yayoi-Kofun, Kofun-Kamakura, Kamakura-Muromachi, Muromachi-Edo, and Edo-Modern were insignificant and, in all, 11 of the 15 MMDs between the six post-Jomon cranial series were insignificant. On the contrary, the MMDs between the Jomon and post-Jomon series were all significant.

In Fig. 1, the measures of divergence from the modern Japanese expressed in standardized deviations (MMD/SD) are depicted for the six cranial series. The standardized deviations in the post-Jomon cranial series were all less than 3.0, whereas in the Jomon it was 11.0, almost four
times as large as that in the Yayoi (see the last column of Table 3).

Principal coordinate analysis was performed on the MMD matrix in Table 3 in order to graphically represent the mutual relationships of the seven cranial series concerned. Fig. 2 is a one-dimensional display of the result. The first axis explains 88.2 percent of the total variance. Again in this figure, the Jomon series is isolated from all the six post-Jomon cranial series which are lumped together within a narrow range.

Discussion and Conclusion

The results of both the univariate comparison and multivariate analysis revealed a clear difference between the Jomon and Yayoi in the incidence pattern of the 22 nonmetric cranial traits. All the Yayoi crania used for this study were unearthed at Kanenokuma and various other sites in northern Kyushu; according to NAKAHASHI and NAGAI (1989), most of them belong to the Middle Yayoi period between about 100 B.C. and 100 A.D. The northern Kyushu Yayoi represented by these crania are widely accepted as consisting of continental immigrants and their offspring (KANASEKI, 1959; NAKAHASHI et al., 1985; NAKAHASHI and NAGAI, 1989). Accordingly, it is not curious that there is a great difference in the incidence pattern of nonmetric cranial traits between the Jomon, native inhabitants of Japan, and the Yayoi of continental lineage.

On the other hand, the result of FISHER’S exact probability test given in Table 2 indicates that the occurrence of these traits has been quite stable during the 2,000 years from the Yayoi period to the present time in northern Kyushu and Honshu. This stability of nonmetric cranial trait occurrence is confirmed by the MMDs computed from the incidence of the 22 traits. As shown in Table 3, the MMDs are insignificant in the comparisons of Yayoi-Kofun, Kofun-Kamakura, Kamakura-Muromachi, Muromachi-Edo, and Edo-Modern. Moreover, the

| Table 3. MMDs, their standard deviations (SD) and standardized deviations (MMD/SD)1) | (MMD: left lower half, SD: parenthesis of left lower half, MMD/SD: right upper half) |
|---|---|---|---|---|---|---|---|
| Jomon | Yayoi | Kofun | Kamakura | Muromachi | Edo | Modern |
| Jomon | | | | | | |
| Yayoi | 0.1363 (0.0114) | | | | | |
| Kofun | 0.0875 (0.0115) | 0.0001 (0.0067) | | | | |
| Kamakura | 0.1170 (0.0116) | 0.0069 (0.0064) | 0.0051 (0.0065) | | | |
| Muromachi | 0.1424 (0.0118) | 0.0024 (0.0070) | 0.0048 (0.0072) | 0.0029 (0.0069) | | |
| Edo | 0.1229 (0.0103) | 0.0122 (0.0053) | 0.0020 (0.0054) | 0.0042 (0.0051) | 0.0057 (0.0058) | | 0.35 |
| Modern | 0.1100 (0.0100) | 0.0139 (0.0049) | 0.0115 (0.0051) | 0.0100 (0.0054) | 0.0065 (0.0055) | 0.0013 (0.0037) |

1) When MMD/SD $\geq 2$, MMD is significant at the 0.05 level. MMDs within the solid line frame are insignificant.
2) Negative MMD values were replaced by zeroes.
standardized deviation of MMD from the modern Japanese is less than 3.0 in the Yayoi, Kofun, Kamakura, Muromachi, and Edo series, whereas that in the Jomon amounts to 11.0 (Fig. 1). Almost the same result is seen in Fig. 2, which is constructed by principal coordinate analysis of the MMDs: the Yayoi, Kofun, Kamakura, Muromachi, Edo, and Modern series are very closely related to each other, while the Jomon is isolated from them.

Taking all these results into consideration, it is inferred that the six cranial series of the post-Jomon periods in the central islands of Japan are samples taken from a population which is distinct from that of the Jomon. Accordingly, the northern Kyushu Yayoi of continental lineage must be one of the lineal forerunners of the modern Japanese of the central islands of Japan.

Of the 22 nonmetric traits used, five – the supraorbital foramen, biasterionic suture vestige, hypoglossal canal bridging, medial palatine canal and transverse zygomatic suture vestige – play a large part in discriminating between the Jomon and the Yayoi of northern Kyushu, as apparent from Table 2. Thus, in order to unequivocally determine the populational discontinuity between the Jomon on one hand and the Yayoi and their probable descendants on the other, we have to elucidate the genetic aspects of these nonmetric traits using appropriate materials and methods in future.

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Yukio DODO
Department of Anatomy, Sapporo Medical College
South 1, West 17, Chuo-ku, Sapporo 060, Japan