Racial Differences in Dimensional Traits of the Human Face

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This paper will use the term "race" loosely as though it is synonymous with the term "ethnic group." This approach is being used because many persons have attempted to define or classify Homo sapiens into racial groups but have not been able to find a satisfactory definition or classification other than the three major racial stocks, i.e., Asiatic, Black and White,[15,49] or possibly a separate stock (Australoids) in the South Pacific. A more recent term "ethnic group" refers to a nation or population with a common bond such as a geographical boundary, a culture or language, or being racially or historically related.[5]

The purposes of this study were: 1) to do a study on the quantifiable somatic traits of the face of American Blacks with acceptable occlusion, 2) to review most of the available data on the quantifiable dimensional traits of the somatic portion of the human face reported in the literature, and 3) to take these data and the data from this study to compare facial traits of the various ethnic groups, looking for similarities and differences of mean data within ethnic groups and between ethnic groups. This study is limited to the somatic facial traits. The dental and alveolar traits are not included.

CEPHALIC MORPHOLOGY

Since the face is attached to the cranium, a brief statement on the morphology of the cranium is warranted. Krogman[41] has pointed out that on the average the heads of American Blacks and American Whites are mesocephalic in shape. Todd[71] noted that there are not any significant differences in brain size and cranial capacity of American Blacks and Whites. Tobias[70] concluded that there is no evidence to determine a difference in the size of the brain of Whites and Blacks. He further recognizes that the differences in brain size among various racial or population groups are negligible, once allowances have been made for body size. It should be noted that figures quoted for cranial size are averages for each group. Individuals within each group vary above and below the average with considerable overlap occurring. Adeloye, Kattan and Silverman[1] found great similarity in the size of skulls of American Blacks and Whites with the frontal bone being thicker in White males than Black males; the parietal and occipital bones are slightly thicker in Blacks. Richardson and Malhotra[55] found the size of the heads of the two racial groups to be similar and also[54] the anteroposterior dimension of the anterior cranial base to be a little larger in American Blacks than in American Whites. Altemus[3] noted the overall size of heads and faces of Negro children compared with Whites to be larger for each sex and age group; the study was done by superimposing cephalic tracings on a line tangent to the anterior cerebral fossa. Glanville[28] found the mean size of the cranial base to be similar in Negro and European skulls. Smith,[59] studying a group of economically deprived Blacks with a mixture of malocclusions, indicated that the cranial base flexure in Blacks

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is greater than in Whites. On the other hand, he has noted that the nasion-sella-basion angle is larger in Blacks than in Whites and that the anterior cranial base is shorter in Blacks. Enlow[24] wrote that the cranium of East Asians tends to be brachycephalic and the cranial base of these Asians is more closed, while that of Whites is more closed in the brachycephalic group and more open in the dolichocephalic group. Furthermore, the cranium of Blacks tends to be dolichocephalic and the cranial base in Blacks tends to be more open.

Materials and Methods

A modified random sampling technique was used to select lateral cephalograms on 40 American Blacks with acceptable occlusion. The cephalograms were taken from the growth study at Meharry Medical College using standard cephalometry. The sample was equally divided between males and females. The ages ranged from 13-16 years. To facilitate comparison with other studies the following measurements were taken: facial angle, sella-nasion-subspinale (point A) angle, sella-nasion-supramentale (point B) angle, sella-nasion-pogonion angle and mandibular plane angle. The data were analyzed as a group and separately for each sex. The cephalograms were traced and the angles measured with a standard protractor. The data were recorded and the means and standard deviations computed (Table I).

A narrative comparison was made of the mean data of the various ethnic groups reported in the literature and the data on this study. The ethnic groups were not separated by sex to facilitate comparison of prior studies. Statistical analyses were made of the means *within* the various ethnic groups and the means *among* the various ethnic groups to elucidate differences and similarities. The t-test was the statistical instrument used to help analyze the data.

TABLE I

The Meharry Sample
Twenty Males, Twenty Females

Angles	*Males*	*Females*
Facial	85.3 ± 3.5	85.6 ± 3.5
SNA	84.0 ± 2.7	84.0 ± 2.8
SNB	79.3 ± 2.9	79.2 ± 2.9
SNPog	79.6 ± 3.1	79.6 ± 3.0
Mand. Plane	28.7 ± 5.6	28.5 ± 5.4

Chart I illustrates the mean facial angle plus or minus one standard deviation of several ethnic groups. The ethnic groups are: (A) Australian Aborigine-Graven; (B) American Black-Altemus; (C) American Black-Cotton; (D) American Black-Meharry Group; (E) American White-Downs; (F) American White-Taylor and Hitchcock; (G) American Mexicans-Garcia; (H) Chinese Cantonese-Gordon; (I) Hawaiian-Choy; (J) North Indian-Nanda; (K) Japanese American-Takano and (L) Japanese Tokyo-Lizuka.

Chart II mandibular plane angle, mean and one standard deviation of several ethnic groups. The ethnic groups are depicted as follows: (A) Australian Aborigine-Craven; (B) American Black-Altemus; (C) American Black-Cotton; (D) American Black-Drummond; (E) American Black-Meharry Group; (F) American White-Downs; (G) American White-Taylor and Hitchcock; (H) American Mexicans-Garcia; (I) Chinese American-Wong; (J) Chinese Cantonese-Gordon; (K) Hawaiian-Choy; (L) North India-Nanda; (M) Swedish-Björk; (N) Japanese American-Takano and (O) Japanese Tokyo-Lizuka.

Chart III the mean sella-nasion-pogonion angle and one standard deviation of several ethnic groups. The ethnic groups are as follows: (A) Australian Aborigines-Brown; (B) Australian Aborigines-Craven; (C) American Black-Drummond; (D) American Black-Meharry Group; (E) American White-Taylor and Hitchcock; (F) Bantus Africa-Craven; (G) Chinese Australia-Wei; (H) Chinese Cantonese-Gordon; (I) Hawaiian-Choy and (J) Swedish-Björk.

Chart IV sella-nasion-point B angle, mean and one standard deviation, of several ethnic groups. The groups are: (A) Australian Aborigine-Craven; (B) American Black-Drummond; (C) American Black-Meharry Group: (D) American White-Steiner; (E) American White-Taylor and Hitchcock; (F) American Mexican-Garcia; (G) Bantus Af-

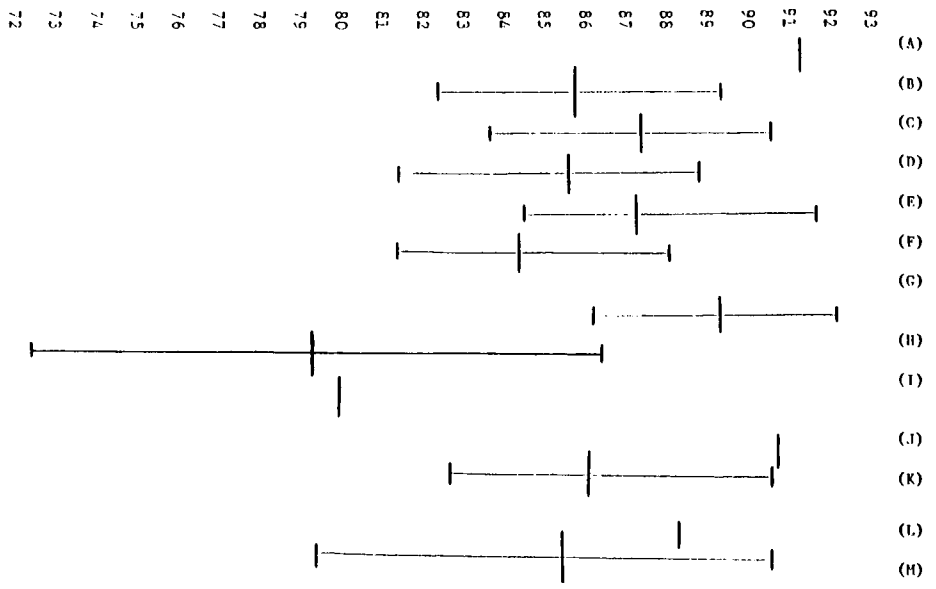

Chart I. Facial angle

rica-Craven; (H) Chinese Australia-Wei; (I) Chinese Cantonese-Gordon; (J) Hawaiian-Choy; (K) Swedish-Björk; (L) Japanese Tokyo-Miura and (M) Japanese Tokyo-Lizuka.

Chart V the mean sella-nasion-point A angle with one standard deviation of several ethnic groups. The ethnic groups are depicted as follows: (A) Australian Aborigine-Brown; (B) Australian Aborigine-Craven; (C) American Black-Drummond; (D) American Black-Meharry Group; (E) American White-Steiner; (F) American White-Taylor and Hitchcock; (G) American Mexicans-Garcia; (H) Bantus Africa-Craven; (I) Chinese Australia-Wei; (J) Chinese Cantonese-Gordon; (K) Hawaiian-Choy; (L) Swedish-Björk; (M) Japanese Tokyo-Miura and (N) Japanese Tokyo-Lizuka.

Our next step is to look at traits of the face in different ethnic groups. For the sake of clarity we shall continue to divide the bony face into several aspects, namely, facial angle, mandibular plane angle, sella-nasion-pogonion, sella-nasion-point B, and sella-nasion-point A.

Chart One

The facial angle relates the plane formed by the exterior surface of the frontonasal suture and pogonion to the Frankfort horizontal plane. It gives an indication of the relative protrusion or retrusion of the chin to the point nasion. The literature reveals a striking similarity of the facial angle in the different ethnic groups. Only the mean facial angles of the American Chinese and Chinese Cantonese show a significant variance from the mean facial angle of other ethnic groups. The mean facial angle varied from 79.5 degrees in American Chinese to 91.5 degrees in Australian Aborigines. Otherwise, there is little difference in the position of the bony facial plane of the ethnic groups.

Chart Two

The cant of the mandibular plane ranged from a low of 18.9 (Hawaiian) to a high of 36.5 (Swedish—Björk).

Chart Three

The sella-nasion-pogonion angle is another parameter relating the position of the chin to the outer surface

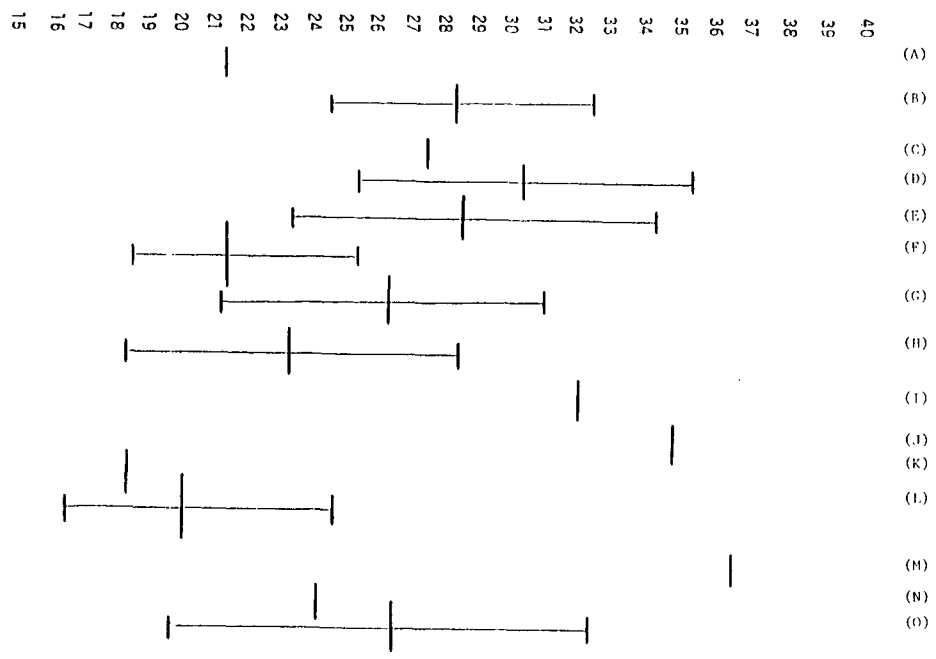

Chart II. Mandibular plane angle

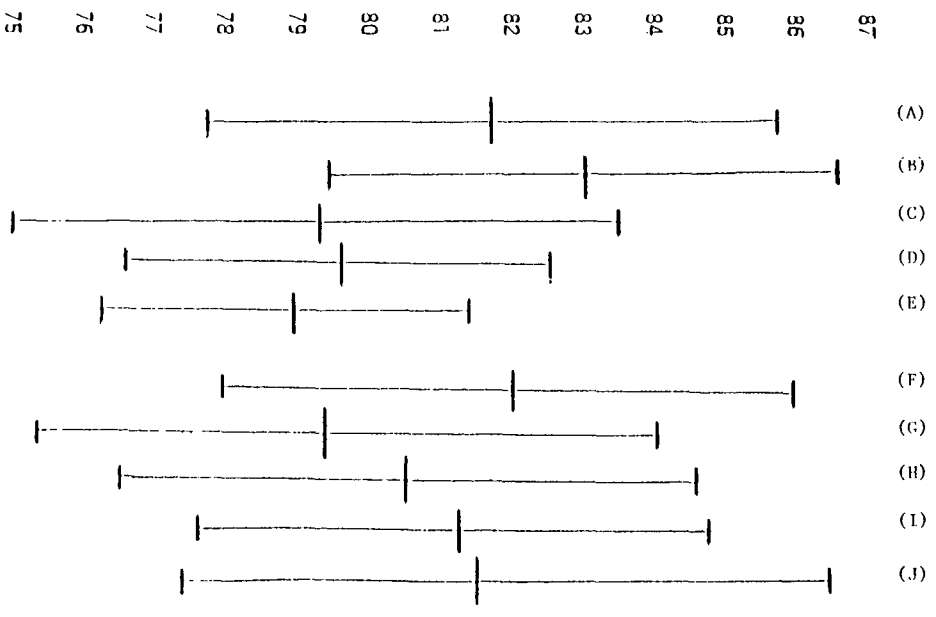

Chart III. Sella-nasion-pogonion

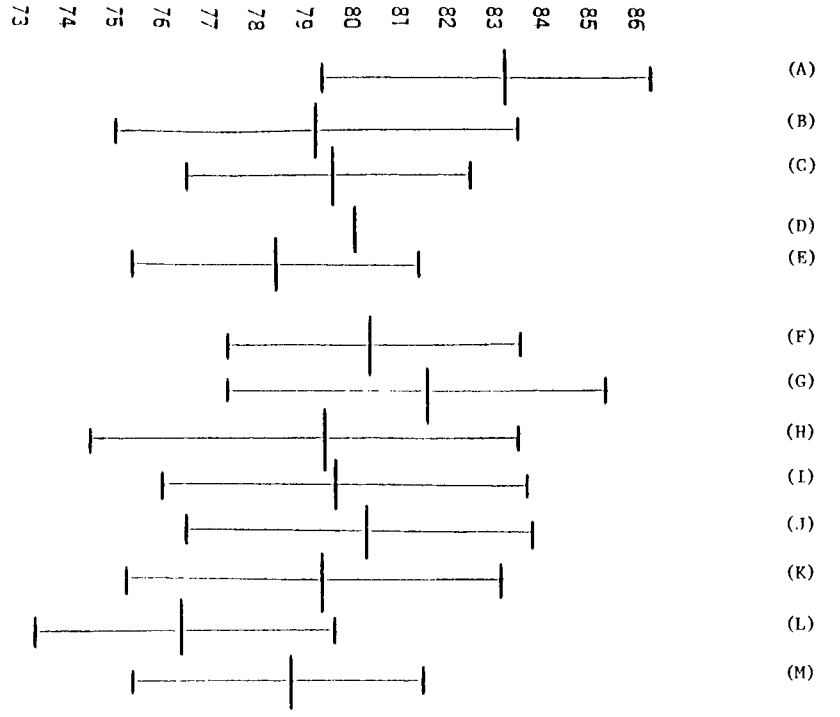

Chart IV. Sella-nasion-point B

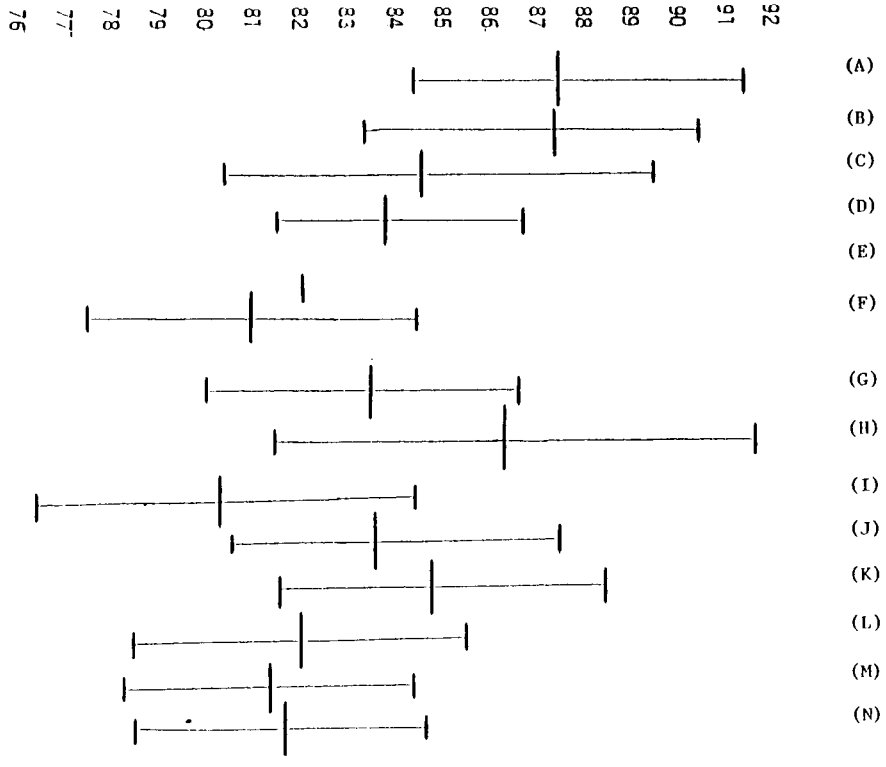

Chart V. Sella-nasion-point A

of the frontonasal suture. There is a striking similarity of this angle in the various ethnic groups. The largest mean sella-nasion-pogonion angle is seen in the Australian Aborigines with 83 degrees followed by the Bantus of Africa with 82 degrees.

Chart Four

The sella-nasion-point B angle indicates the relative position of the anterior portion of the basal bone of the mandible to the outer surface of the frontonasal suture. It ranges from 76.8° (Tokyo Japanese) to 83.1° (Australian Aborigines).

Chart Five

Sella-nasion-point A relates the anterior portion of the basal bone of the maxilla to the outer surface of the frontonasal suture. Again the Australian Aborigines have the largest angle (87.1°). The smallest angle (81°) was found in Alabama Whites.

Statistical Analysis of Data

To conserve space a report is given only for American Blacks, American Whites and Japanese.

1. Facial angle: The differences in the mean facial angles of American Blacks from the North, American Whites from the North, and Japanese were not statistically significant. The differences in the mean facial angles of American Blacks from the South and American Whites from the South were not statistically significant. The differences in the mean facial angles of Northern Whites and Southern Whites were statistically significant at the one percent level of confidence.

2. Mandibular plane angle: There was a statistically significant difference in the mandibular plane angle in most groups compared.

3. Sella-nasion-pogonion: The differences in the mean angles of Southern Blacks and Southern Whites were not statistically significant. Adequate data were not available on Northern Americans and Japanese.

4. Sella-nasion-point B: The differences in the mean angles of Southern Blacks and Southern Whites were not statistically significant. Adequate data were not available on Northern Americans and Japanese.

5. Sella-nasion-point A: The differences in the mean angles of Southern Blacks and Southern Whites were significant statistically. Adequate data were not available on Northern Americans and Japanese.

Discussion

Ethnic differences in facial traits do exist. The question is their magnitude. Are the differences genetic in the sense of what we usually think of genetic factors, or are the differences to a greater extent related to geographic and ecological factors with forces responsible for their being passed on from generation to generation being as much cultural and behavioral as hereditary?

Factors Affecting Cephalofacial Form

The human being, like other animals, is responsive to ecological factors. Several authors have written about the plasticity of the human organism in response to changes in the environment. Other authors, Dahlberg,[19] Hulse[35] and Schreider[57] have taken another approach to the situation. They have advocated a genetic explanation of heterosis due to a breakdown of breeding isolates.

Apparently the environment affects the proportions of the physiognomy of ethnic groups. Boas[8] made observations on physical changes in the American-born progeny of immigrants from several European countries. He found significant differences in stature, weight, head shape and facial

width. The observations of Boas were confirmed by other investigators including Guthe,[30] Hirsch,[31] Weitzman,[74] Lasker,[42] Shapiro,[58] and Froehlich.[25]

There are several theories and philosophies relative to the effects of temperature on head shape and facial form. There have been definite suggestions of an adaptability of facial form and engineering to temperature.[13-15,20,27,33,73] This concept is further emphasized by Beals[6] who indicated that there is an inverse relationship between the mean cephalic index and temperature. Koertvelyessy[40] indicated a correlation between the frontal sinuses and climatic conditions. He particularly supports Coon, Garn, and Birdsell.[15]

Steegmann[61] seems to disagree with Coon, Garn and Birdsell relative to the "Cold Engineered Face" but agrees that a few physical traits are related to temperature. He[61,63] denied an association of temperature and facial form but after more in-depth study found some correlations between facial form and temperature.

There are others who feel that cephalofacial form is determined entirely by hereditary factors. Brodie[9] stated that apart from the alveolar process and teeth, the skeletal pattern is genetically determined.

Only a very small amount of the known genetic material, maybe one to two percent, is responsible for the physical characteristics that distinguish one group from another or one person from another. In other words, only one to two percent of genetic material is involved in creating the physical differences between Blacks, Whites, Browns, Yellows and Reds according to Comer and Poussaint.[12]

It has been inferred that bone cells may undergo morphologic transformation by hormones according to Miller, Wolf and Armand.[46]

Function has been attributed as a factor affecting body form including cephalic and facial morphology. D'Arcy Thompson[69] was an early proponent of this philosophy. Since the works of Thompson, many others have supported this concept either in part or totally. Some made observations on the effect of the absence of function and reduced function on facial morphology. Others noted alterations due to altered function. Some researchers supporting the effect of function on facial form are Horowitz and Shapiro,[32] Nanda, Merrow and Sassouni,[51] McNamara,[45] Moller,[48] Ingervall and Thilander,[37] Ringqvist,[56] Ahlgren,[2] Solow,[60] and Moss.[50] Moss quotes Van Der Klaauw.[39]

Burston, Hamilton and Walker[10] stated that an essential factor affecting form is that if the external environment is changed, it is not transmitted to the next generation but that the external environment can act on genes and genes can act on the internal environment of a cell. Those actions can alter the dimensions of the face. Lundstrom[43] noted that the skeletal pattern is innately conditioned to a certain degree, but that even identical twins have certain differences in skeletal patterns which must be caused by nongenetic factors. In a later study Lundstrom[44] found facial differences in identical twins that are not attributable to genetics.

An Analysis of Measurements

An analytical look at data on the different ethnic groups raises several issues. The means of different groups within an ethnic or racial group show as much difference as the means between two ethnic or racial groups. This is vividly seen in comparing the facial angle of midwestern American Whites in the study by Downs[16] with the facial angle obtained in the southern region on American Whites by

Taylor and Hitchcock.[68] The means are 87.6 degrees with a standard deviation of 3.57 and 84.7 degrees with a standard deviation of 3.30, respectively. The means of either sample are closer to the means of samples on northern American Blacks by Cotton and southern Blacks from Tennessee which were 87.25 degrees and 85.43 with standard deviations of 3.36 and 3.53 degrees, respectively. A statistical comparison confirms this observation. There is a statistically significant difference in the means of northern Whites as measured by Downs and southern Whites as measured by Taylor and Hitchcock ($t = 3.3554$). Comparing northern Blacks (Northern California) with northern Whites, the difference in means is not statistically significant ($t = .5938$). The same holds true in comparing southern Blacks (Tennessee) and southern Whites ($t = 1.7663$). However, when southern Blacks are compared with northern Whites or northern Blacks with southern Whites, the differences in the means are significant statistically with $t = 2.4949$ and $t = 2.7933$, respectively. A similar statement can be made relative to the mean facial angle of either of the aforementioned groups with the Japanese of America 88.25 degrees, and of Tokyo 85.07 degrees with a standard deviation of 5.76.

The surprising similarity in the mean facial angle among the ethnic groups in the same geographic region is reinforced by an equally similar value for the sella-nasion-pogonion angle. The uniformity is even greater if one confines the observations to a single geographic region. In Australia the Aboriginals are mainly divergent from what we know of Whites in the U. S., but whether they show similarities to the present-day Whites of Australia is worth further examination.

When one leaves what are considered to be the more stable areas of the face and looks at the mandibular plane angle, a greater variability is seen in the mean figures among the ethnic groups. There is also variation within ethnic groups. Since the mandibular plane angle is influenced by the wear of the occlusal surfaces of the teeth and the degree of eruption of the teeth, one is not surprised to see the variation in this parameter. The data would seem to indicate that the Hawaiians have the most parallel mandibular plane followed by the Indians from India, Australian Aborigines and American Whites, American Mexicans, Japanese, American Blacks, Chinese and Swedes. This dimension would affect the appearance of the face, particularly the assessment of posterior and anterior face-height relationships.

The summations of the data lead one to feel that writers showing extreme morphological differences in the various ethnic groups could possibly have drawn samples from a segment at one end of the profile scale of the group, rather than drawing a sample that could be considered a microcosm of the particular group. The differences could also represent the comparison of two or more ethnic groups from different geographic regions where the differences are primarily due to geographic factors rather than racial factors. The mean data with standard deviations indicate a great overlap in quantitative measurements (Charts 1-5).

As expected, one finds more variance of the sella-nasion-point A and sella-nasion-point B dimensions among the races. The divergence is relatively small. It is not nearly as great as expected and usually stated. These parameters seem to reflect their interface with the alveolar bone and

teeth. When one eliminates the Australian Aboriginals, the mean data are surprisingly similar. Maxillary prognathism becomes reduced as one proceeds from the Australian Aborigine, Bantu, Hawaiian, American Black, Chinese, American Mexican, Swedish, Japanese, to the American White.

This writer questions some investigators' inferences of their being able to accurately identify the various ethnic groups from somatic skull material, excluding the teeth, except in the more extreme cases. He wonders whether we have more than one race, but instead ethnic groups separated by cultural, climatic and geographic boundaries that have caused subtle changes in facial morphology. This writer questions whether the changes have reached genetic stability or whether they are still in a state of genetic drift.

Conclusions

1. Race is difficult to define at best and references to groups are more accurately made on the basis of ethnic groups that are bound by some common bond, such as Swedish Whites, American Whites, etc.

2. The quantifiable differences in the somatic craniofacial region of ethnic groups residing for several generations in the same or similar geographic areas are small.

3. The evidence supports a geographical effect on the most frequently used quantifiable angular measurements of the somatic facial profile of the major racial groups.

4. Cephalofacial morphology is affected by many factors including genetics, function and temperature.

5. There are mean differences in the quantifiable traits of the face of some ethnic groups. The differences in means *within* ethnic or racial groups are often greater than the differences in means *among* ethnic or racial groups.

6. The differences in means of traits of the somatic facial skeleton among or between ethnic groups are usually very small with an enormous degree of overlap.

7. The parameters of the face that are closer to the alveolar and dental areas show the greatest differences among ethnic and racial groups.

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References

1. Adeloye, Adeloal, Kenneth R. Kattan and Frederic N. Silverman: Thickness of normal skull in American blacks and whites. *Am. J. Phys. Anthrop.*, 43:23-30, 1975.
2. Ahlgren, J.: Mechanism of mastication. A quantitative cinematographic and electromyographic study of masticatory movements in children, with special reference to occlusion of the teeth. *Acta Odont. Scand.*, 24 (Suppl.):44, 1966.
3. Altemus, Leonard A.: Comparison of cephalofacial relationships. *Angle Orthod.*, 30:223-240, 1960.
4. Avis, V.: The significance of the angle of the mandible: An experimental and comparative study. *Am. J. Phys. Anthrop.*, 19:55-61, 1961.
5. Barnhart, Clarence L.: *The American College Dictionary*. Random House, New York, p. 413, 1953.
6. Beals, Kenneth L.: Head form and climatic stress. *Am. J. Phys. Anthrop.*, 37: 85-92, 1972.
7. Björk, A.: The face in profile. S. B. Tandl. Tidskr. 40 Suppl. Berling Ska Boktryckereit, Lund.—Quoted in A. H. Craven. (1958) A radiographic cephalo metric study of the central Australian aboriginal. *Angle Orthod.*, 28:12-35, 1947.
8. Boas, F.: Changes in bodily form in the descendants of immigrants, U.S. Immigration Commission. Government Printing Office. Washington, D.C., 1911.
9. Brodie, A. G.: Discussion on Orthodontics, *Internat. Dent. J.*, 3:601-606, 1953.
10. Burston, W. R., W. J. Hamilton and D. Greer Walker: Symposium: Malformation of the face. *Brit. Dent. J.*, 116:285-294, 1963.
11. Choy, Oliver W. C.: A cephalometric study of the Hawaiian. *Angle Orthod.*, 39:93-108, 1969.

12. Comer, James P. and Alvin F. Poussaint: *Black Child Care,* Simon and Schuster, New York, pp. 16-58, 1975.
13. Coon, C. S.: *The Origin of Races.* Knopf Publisher, New York, pp. 533-534, 1962.
14. ———: Some problems of human variability and natural selection in climate and culture. *Amer. Nat.* 89:257-279, 1955.
15. Coon, C. S., S. M. Garn and J. B. Birdsell: *Races: A Study of the Problems of Race Formation in Man.* Charles C Thomas, Springfield, Illinois, pp. 65-71, 1950.
16. Coon, C. S.: *The Races of Europe,* Macmillan Press, New York. 1939.
17. Cotton, Wendell N., William S. Takano and Wilfred M. Wong: The Downs analysis to three other ethnic groups, *Angle Orthod.* 21:213-220, 1951.
18. Craven, A. H.: A radiographic cephalometric study of the central Australian aboriginal, *Angle Orthod.* 28:12-35, 1958.
19. Dahlberg, G.: *Race, Reason and Rubbish.* Columbia University Press, New York, 1942.
20. Debetz, G. R.: Problems of physical anthropology in arctic regions. *Arta Artica,* 12:61-65, 1958.
21. Downs, W. B.: Variation in facial relationships: their significance in treatment and prognosis, *Am. J. Orthod.* 34:812-840, 1948.
22. Drummond, Richard A.: A determination of cephalometric norms for the Negro race. *Am. J. Orthod.,* 54:670-682, 1968.
23. Dunn, L. C. and Theodosius Dobzhansky: *Heredity, Race and Society Mentor Book,* published by the New American Library, New York, p. 144, 1963.
24. Enlow, Donald H.: *Handbook of Facial Growth.* W. B. Saunders Co., Philadelphia, 1975.
25. Froehlich, J. W.: Migration and the plasticity of physique in the Japanese-Americans of Hawaii. *Am. J. Phy. Anthrop.,* 1970.
26. Garcia, Carlos J.: Cephalometric evaluation of Mexican Americans using the Downs and Steiner analyses, *Am. J. Orthod.,* 68:67-74, 1975.
27. Garn, S. M.: *Human Races.* Charles C Thomas, Springfield, Ill., p. 63, 1965.
28. Glanville, Edward V.: Nasal shape, prognathism and adaptation in man. *Am. J. Phys. Anthrop.,* 30:29-38, 1969.
29. Gordon, Kam-Hung Chan: A cephalometric appraisal of the Chinese (Cantonese), *Am. J. Orthod.,* 61:279-285, 1972.
30. Guthe, C. E.: Notes on cephalic index of Russian Jews in Boston. *Am. J. of Phys. Anthrop.,* 1:213-233, 1917.
31. Hirsch, N. D. M.: Cephalic index of American born children of three foreign groups. *Am. J. Phys. Anthrop.,* 10:79-90, 1927.
32. Horowitz, S. L. and H. H. Shapiro: Modification of skull and jaw architecture following removal of the masseter muscle in the rat. *Am. J. Phys. Anthrop.,* 13:301-308, 1955.
33. Hulse, F. S.: *The Human Species.* Second Edition. Random House, New York, 1971.
34. ———: Adaptation, selection and plasticity in ongoing human evolution. In: *The Processes of Ongoing Evolution,* Gabriel Lasker, ed. Wayne State University Press, Detroit, 1960.
35. ———: Migration and cultural selection in human genetics. *The Anthropologist,* Special Volume 1-21, 1969.
36. Lizuka, T., and F. Ishikawa: Normal standards for various cephalometric analysis in Japanese adults—Japanese male and female adults, *J. Jap. Orthodont. Soc.,* 16:4-12, 1957.
37. Ingervall, B. and B. Thilander: Relation between facial morphology and activity of the masticatory muscles. *J. Oral Rehabil.,* 1:131-147, 1974.
38. Kaplan, B. A.: Environment and human plasticity. *Amer. Anthrop.,* 56:780-800, 1954.
39. Klaauw, C. J. Van der: Cerebral skull and facial skull. A contribution to the knowledge of skull structure. *Arch. Neerl. Zool.,* 9:16-36, 1946.
40. Koertvelyessy, T.: Relationships between the frontal sinus and climatic conditions: a skeletal approach to cold adaptation. *Am. J. Phys. Anthrop.,* 37:161-172, 1972.
41. Krogman, W. M.: *Growth of Head, Face, Trunk and Limbs in Philadelphia White and Negro Children of Elementary and High School Age.* Monograph, Society for Research in Child Development. Serial No. 136, Bol. 35, No. 3, Univ. of Chicago Press, pp. 1-80, 1970.
42. Lasker, G. W.: Migration and physical differentiation. *Am. J. Phys. Anthrop.,* 4: 273-300, 1946.
43. Lundstrom, A.: Discussion on orthodontia, *Internat. Dent. J.,* 3:601-606, 1953.
44. Lundstrom, Anders: Size of teeth and jaws in twins, *Brit. Dent. J.,* 117:321-326, 1964.
45. McNamara, J. A., Jr.: Neuromuscular and skeletal adaptations to altered function in the orofacial region. *Am. J. Orthod.,* 64:578-606, 1973.
46. Miller, Sam S., Alice M. Wolf and Claude D. Armand: Bone cells in culture: Morphologic transformation by hormones. *Science,* 192:1340-1343, 1976.
47. Miura, F., Naohiko Inoue and Kazuo Suzuki: Cephalometric standards for Japanese according to the Steiner analysis, *Am. J. Orthod.,* 51:288-295, 1965.
48. Moller, E.: The chewing apparatus. An electromyographic study of the action of the muscles of mastication and its corre-

lation to facial morphology. *Acta Physiol. Scand.,* 69 (Suppl.):280, 1966.

49. Montague, Ashley: *Man's Most Dangerous Myth: The Fallacy of Race,* Columbia University Press, New York, 1942.
50. Moss, M. L.: Functional analysis of human mandibular growth. *J. Prosth. Dent.,* 10:1149-1159, 1960.
51. Nanda, S. K., W. W. Merow and V. Sassouni: Repositioning of the masseter muscle and its effect on skeletal form and structure. *Angle Orthod.,* 37:304-308, 1976.
52. Nanda, Ravindra and Ram S. Nanda: Cephalometric study of the dentofacial complex of north Indians, *Angle Orthod.,* 39:22-28, 1969.
53. Newman, M. T.: Biological adaptation of man to his environment; heat, cold, altitude and nutrition. *Ann. N.Y. Acad. of Science,* 91:617-633, 1961.
54. Richardson, E. R. and S. K. Malhotra: Growth of the anterior cranial base in human males. *J. Dent. Res.,* 55:B105 (abs), 1976.
55. Richardson, Elisha R. and Shyam K. Malhotra: Vertical growth of the anterior face and cranium in inner city Negro children. *Am. J. Phy. Anthro.,* 41:361-366, 1974.
56. Ringqvist, M.: Isometric bite force and its relation to dimensions of the facial skeleton. *Acta Odont. Scand.,* 31:35-42, 1973.
57. Schreider, E.: Body height and in breeding in France. *Am. J. Phys. Anthrop.,* 26: 1-4, 1967.
58. Shapiro, H. L.: *Migration and Environment.* Oxford Univ. Press, New York, 1939.
59. Smith, Nelson L.: A bi-racial study of facial morphology. Master's Thesis, *Univ. of Michigan,* p. 29, 1970.
60. Solow, B. and A. Tallgren: Head position and craniofacial morphology, *J. Dent. Res.* (abs) 54:145 (special issue), 1975.
61. Steegmann, A. T., Jr.: A study of relationships between facial cold response and some variables of facial morphology. *Am. J. Phys. Anthrop.,* 23:355-362, 1965.
62. ———: Cold response, body form, and craniofacial shape in two racial groups of Hawaii. *Am. J. Phys. Anthrop.,* 37:193-222, 1972.
63. ———: Cold adaptation and the human face. *Am. J. Phys. Anthrop.,* 6:243-250, 1970.
64. Steiner, Cecil C.: Cephalometrics for you and me, *Am. J. Orthod.,* 39:729-755, 1953.
65. ———: Cephalometrics in clinical practice, *Angle Orthod.,* 29:8-29, 1959.
66. Tanner, J. M.: *Growth at Adolescence.* Thomas Publishers, Springfield, Illinois, 1962.
67. ———: Growth and physique in different populations of mankind. *In the Biology of Human Adaptability.* Paul T. Baker and J. S. Weiner, eds., Claredon Press, Oxford, 1966.
68. Taylor, Wendell H. and H. Perry Hitchcock: The Alabama analysis, *Am. J. Orthod.,* 52:245-265, 1966.
69. Thompson, D'Arcy: *On Growth and Form.* London, Cambridge Press, 1942.
70. Tobias, Phillip V.: Brain size, gray matter and race fact or fiction. *Am. J. Phys. Anthrop.,* 6:97-194, 1970.
71. Todd, T. M.: Cranial capacity and linear dimensions in white and Negro. *Am. J. Phys. Anthrop.,* 6:97-194, 1970.
72. Wei, Stephen H. Y.: A roentgenographic cephalometric study of prognathism in Chinese males and females, *Angle Orthod.,* 38:305-320, 1968.
73. Weidenreich, F.: The brachycephalization of recent mankind. *S. W. Journal Anthropology,* 1:1-54, 1945.
74. Weitzman, F.: Changes in the cephalic index of second generation Russian Jews. Master Thesis. *Columbia University,* Department of Anthropology, 1947.