Richard L. Jantz,[1] *Ph.D.*

Cranial Change in Americans: 1850–1975

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ABSTRACT: This paper examines the pattern and magnitude of craniofacial change in American blacks and whites over the past 125 years. Standard metric data from 885 crania were used to document the changes from 1850 to 1975. Data from 19th century crania were primarily from anatomical collections, and 20th century data were available from the forensic anthropology data bank. Canonical correlation was used to obtain a linear function of cranial variables that correlates maximally with year of birth. Canonical correlations of year of birth with the linear function of cranial measurements ranged from 0.55 to 0.71, demonstrating that cranial morphology is strongly dependent on year of birth. During the 125 years under consideration, cranial vaults have become markedly higher, somewhat narrower, with narrower faces. The changes in cranial morphology are probably in large part due to changes in growth at the cranial base due to improved environmental conditions. The changes are likely a combination of phenotypic plasticity and genetic changes over this period.

KEYWORDS: forensic science, secular change, cranial morphology, forensic anthropology, Ellis R. Kerley

Ellis Kerley was at the University of Kansas during my Ph.D. work. I took his paleopathology course and he was a member of my doctoral committee. Ellis fostered an early interest in forensic anthropology and recruited me as one of the early members of the newly formed physical anthropology section of the American Academy of Forensic Sciences. Ellis also played a critical role in the establishment of the forensic anthropology data bank, from which a large part of the sample used in this study was obtained. He told me after it received National Institute of Justice funding that he had been consulted about its merits and that he had supported it. I doubt funding would have been forthcoming without that support. Hence it is with gratitude that I dedicate this paper to the memory of Ellis Kerley.

The original purpose of the forensic anthropology data bank was to provide up-to-date identification criteria for estimation of ancestry, sex, age, and stature, rather than having to rely on 19th century anatomical collections. A benefit of the data bank, not clearly foreseen at the time, concerns its potential to document the ever-changing skeletal morphology of the American population. It has been shown previously that certain cranial variables exhibit striking change over the past 1.5 centuries in American blacks and whites (1,2). The variable showing the most remarkable change is vault height. Other variables, including vault breadth, face breadth, and base length are also correlated with year of birth.

Univariate analyses clearly demonstrate that cranial morphology has changed and suggest something of the pattern. However, univariate analysis does not address the integrated aspects of craniofacial morphology. The question to be addressed in this paper is whether a linear function of cranial variables, weighted in such a way as to maximize its correlation with year of birth, will provide more insight into craniofacial change. This procedure, known as canonical correlation, will also provide an overall measure of strength of association between year of birth and cranial morphology.

Materials and Methods

Table 1 shows distribution of crania by group, sex, and birth year cohort. Birth years were grouped into two 50-year and one 25-year birth year cohorts to show the temporal distribution of the sample. For each individual the year of birth is known, and these individual birth years were used in the analysis. Those with birth years in the 19th century are mainly from the Terry and Todd anatomical collections, while those with 20th century birth years are mainly from the forensic anthropology data bank.

Canonical correlation was implemented using the SAS procedure CANCORR. CANCORR derives linear functions of a set of x variables and a set of y variables that are maximally correlated. In the present application, there is only one x variable, year of birth, so CANCORR yields a linear function of cranial variables that correlates maximally with year of birth. The analysis was carried out using 15 standard cranial measurements.

Results

Table 2 presents the canonical correlation of year of birth with cranial variables. For comparison, basion-bregma height, the single variable showing the highest correlation with year of birth, is shown. The canonical correlation and the univariate correlation of basion-bregma height with year of birth are both highly significant in all groups, and in all groups the maximized correlations show a marked improvement over the univariate. The strength of association is higher in whites than in blacks and highest in white males. These correlations are astonishingly high; they imply that between 30 and 50% of the variation of the cranial canonical score can be explained by year of birth.

Figure 1 shows the scatter plot of the cranial canonical scores in relation to year of birth with a fitted linear regression line. Linear regressions were run for each group individually, but, since the slopes were very similar, a common regression line is shown. The plot shows a clear increase in the canonical score over the 125 years, from 1850 to 1975, represented in this sample.

[1] Department of Anthropology, University of Tennessee, Knoxville, TN.
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Table 3 shows the canonical structure coefficients, computed as the correlation between the canonical score and the original variables. The structure coefficients show how each variable contributes to the canonical score, which provides insight into how the cranium is changing over the time period considered here. There are several areas of broad similarity among groups, most notably that basion-bregma height is the highest loading in all groups except black males, where occipital chord is slightly higher. Occipital chord is also relatively highly and positively loaded in all groups. Both basion-bregma height and occipital chord reflect the increase in cranial vault height that blacks and whites of both sexes experience. In other dimensions, there are some group differences in the pattern of cranial change, most notably in basion-nasion and basion-prosthion length. Both groups, but especially whites, exhibit an increase in basion-nasion, a reflection of upper facial projection. Whites also exhibit an increase in basion-prosthion, a reflection of lower facial projection, but blacks do not. This pattern of upper facial projection in blacks, but no corresponding increase in lower facial projection, will reduce the amount of apparent prognathism in blacks.

There is some evidence of group difference in the various measures of cranial length. Whites exhibit an increase in overall cranial length, but blacks do not. The white increase in frontal chord must be in part a reflection of the increased cranial base length. In both groups, but especially blacks, parietal chord decreases.

TABLE 1—*Sex and ancestry distribution of sample by birth year cohort.*

	White Males	White Females	Black Males	Black Females
1850–99	103	80	96	84
1900–49	127	74	87	61
1950–75	61	66	17	29

TABLE 2—*Canonical correlation of cranial variables and basion-bregma height with year of birth.*

Sample	Canonical Correlation	*P*	Pearson *r*	Pearson *P*
Black females	0.608	<0.0001	0.303	<0.0001
Black males	0.547	<0.0001	0.299	<0.0001
White females	0.664	<0.0001	0.469	<0.0001
White males	0.710	<0.0001	0.522	<0.0001

TABLE 3—*Canonical structure coefficients.*

Variable	BF	BM	WF	WM
Glabello-occipital lgth	−0.126	0.001	0.304	0.380
Basion-nasion lgth	0.245	0.363	0.591	0.630
Basion-bregma ht.	0.498	0.546	0.707	0.735
Max cranial br.	−0.108	−0.051	−0.325	−0.236
Bizygomatic br.	−0.372	−0.139	−0.313	−0.238
Biauricular br.	0.090	0.153	−0.094	−0.006
Basion prosthion lgth	0.027	0.073	0.401	0.257
Nasion-prosthion ht.	−0.097	−0.010	0.224	0.180
Nasal ht.	0.002	0.121	0.160	0.007
Nasal br.	0.083	−0.091	−0.204	0.025
Biorbital br.	−0.273	−0.015	−0.149	0.068
Frontal chord	0.134	0.171	0.405	0.364
Parietal chord	−0.336	−0.510	−0.114	−0.157
Occipital chord	0.310	0.621	0.464	0.687
Foramen magnum lgth	0.094	−0.139	0.173	0.238

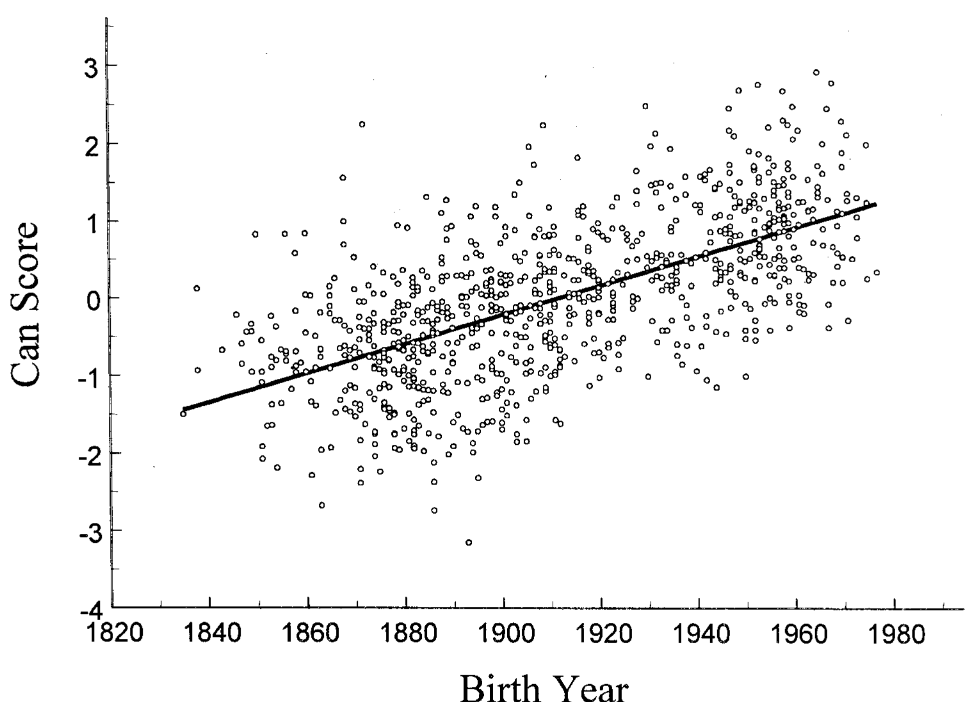

FIG. 1—*Plot of canonical score versus birth year with fitted regression line.*

Bizygomatic breadth is negatively loaded in both groups, indicating a narrowing of the face. In whites it involves maximum cranial breadth as well.

Linear regression does not reveal some of the finer details of variation present in the relationship between birth year and cranial morphology, especially regarding differences between blacks and whites. Figure 2 presents a lowess regression plot for blacks and whites (sexes pooled). It shows the differing pattern of secular change for blacks and whites. Blacks exhibit virtually no change from mid-19th century to the turn of the century. One can even observe a slight post-reconstruction decrease in blacks. However, early in the 20th century, there is a sharp and sustained rise in the black canonical score. Whites, on the other hand, show a gradual increase from mid 19th century to late 19th century, at which time there is a steeper increase, followed by a more gradual increase.

Discussion

The past 125 years have been marked by profound environmental changes: the amount and quality of nutrition has increased, disease and mortality, especially infant mortality, have decreased, and activity levels have decreased, allowing more resources to be diverted to growth and development. Secular changes in stature have been investigated at length and consequently are well known (3–6). Many aspects of cranial form are considered to be genetically persistent over considerable periods of time (7) and hence less susceptible to short-term secular changes. But short-term changes have been documented on a number of occasions (1,8–12). We have known that the cranial vault exhibits plasticity ever since Boas demonstrated it (13), although most applications have still tended to regard the cranium as highly genetic.

If the changes observed in this paper are environmental plasticity, then the skull, like the postcranial skeleton, can be used as a reflection of social circumstances. Angel's papers on skeletal plasticity (8,14) constitute the few examples of using cranial morphology to reflect environmental quality. He specifically argued that skull base height is a measure of growth efficiency, attempting to show that poor nutrition would compromise the ability of the skull base to bear the weight of the brain. The present results also implicate growth at the cranial base and hence support Angel's hypothesis. If the broader changes seen in the present data are phenotypic plasticity resulting from improved health and nutrition, then variation around the regression line may reflect early childhood health and nutrition. If so, then it may be possible to use cranial morphology as a marker of early childhood, or even prenatal, growth sufficiency.

On the other hand, substantial genetic changes over the past 125 years cannot be ruled out. Accompanying improved diet and conquest of infectious disease has been a marked reduction in infant and childhood mortality. Infant mortality has gone from ca. 160/1000 births in the late 19th century to ca. 10/1000 by 1970. Clearly, many infants who survive today would not have survived had they been born in the 19th century. If there are genetic differences between survivors and nonsurvivors with respect to craniofacial growth potential, then relaxation of selection may account for changes in craniofacial morphology.

Like most aspects of human morphology, there are both genetic and environmental components in cranial variation and both likely contribute to the secular change. From the forensic standpoint it is more important to document the secular changes than to understand their causes. Whatever the causes, the unique environment of modern Americans has resulted in a unique craniofacial morphology. Just how unique can be illustrated by examining morphometric relationships of Americans of different birth year cohorts, as set out in Table 1, in relation to European and African samples from Howells' (15) data. Howells' European (Berg, Zalavar, and Norse) and African (Dogon, Teita, and Zulu) samples might be taken to

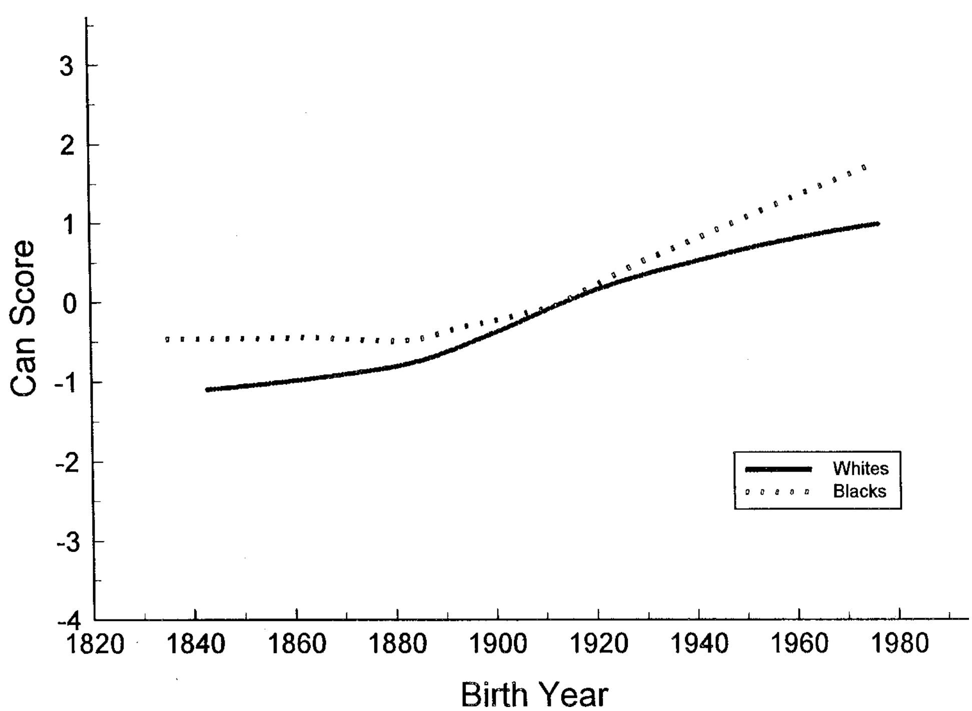

FIG. 2—*Lowess regression plot of canonical score on birth year for blacks and whites.*

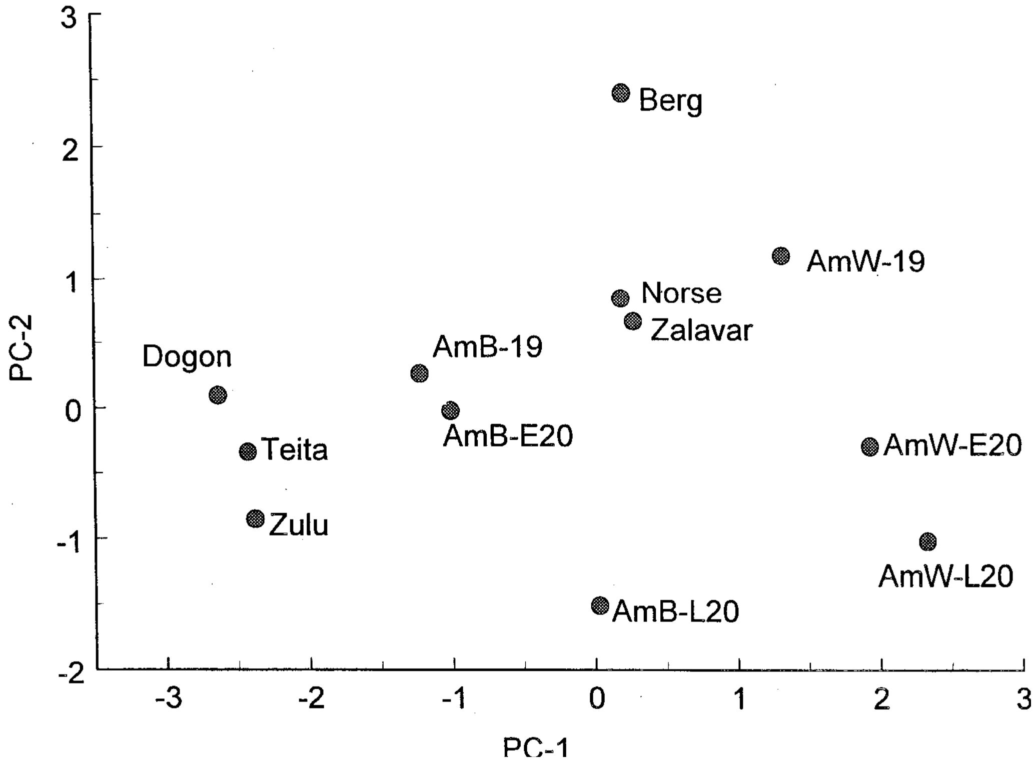

FIG. 3—*Principal coordinates plot showing relationships of African, European and American blacks and whites. American crania are divided into birth year cohorts as shown in Table 1. Cohort codes are: 19 = 19th century, E20 = early 20th century, L20 = late 20th century.*

roughly approximate the ancestral condition of American whites and blacks, respectively.

Figure 3 shows a bivariate plot of distances among the European, African, and the three birth year cohorts of American blacks and whites. It is evident that 19th century American whites are morphometrically similar to European samples, but 20th century samples, especially late 20th century, are strongly differentiated. A similar situation is seen in 19th century blacks, except they are to some degree intermediate between Africans and Europeans, presumably because of admixture and environmental change. Like whites, late 20th century blacks are strongly differentiated from their 19th century ancestors. Most striking about the relationships is that late 20th century whites and blacks are about as similar to each other than either is to its 19th century ancestors.

These results underscore the necessity of basing identification criteria on skeletal samples of recent Americans rather than on 19th century anatomical collections. Craniofacial secular change shows no signs of abating, so it is essential that documentation of future trends continues. That changes can be documented in blacks and whites suggest that other American populations, such as Hispanics and the various Asian and Native American groups, have also experienced change. It, too, should be documented and appropriate samples used to develop identification criteria. Samples of these populations are more difficult to obtain, but the importance of doing so should be obvious.

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