AMERICAN JOURNAL OF HUMAN BIOLOGY 4:235–246 (1992)

Secular Trends of 22 Body Dimensions in Four Racial/Cultural Groups of American Males

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ABSTRACT Data from the recent U.S. Army Anthropometric Survey provide a unique opportunity to assess long-term changes in body dimensions within the Army population. This report considers secular trends for 22 body dimensions within four racial/cultural groups: Whites, Blacks, Hispanics, and Asian/Pacific Islanders. Individuals were grouped by year of birth into 5 year cohorts, spanning 1911 to 1970. Rates of secular change were calculated by regressing age-adjusted dimensions against birth year cohort. Results showed that almost all dimensions sustained statistically significant linear trends, the few exceptions occurring in Asian/Pacific Islanders. The greatest rates of change occurred in dimensions related to soft tissues rather than skeletal dimensions. This pattern is consistent with recent American cultural emphasis on health and physical fitness. The causes of the observed trends, insofar as they have been identified, are related to cultural processes. This suggests that biological forces play a diminished role in shaping the patterns of secular change. Therefore, it may be more appropriate to study secular change in groups that are culturally, rather than biologically, defined.

A secular trend is a progressive change over time. Secular trends in human morphological traits spanning the last 200 years are well documented (Davenport and Love, 1921; Trotter and Gleser, 1951b; Meredith, 1976; McCullough, 1982; Tanner et al., 1982; Steegman, 1985; Ohyama et al., 1987; Harlan et al., 1988). Generally, the trends are descriptions of changes in stature, weight, or the indicators of maturity. Few reports discuss more than a handful of anthropometric dimensions. Data are now available from several anthropometric surveys of the U.S. Army (White and Churchill, 1971; Gordon et al., 1989). These data provide a basis for an analysis of secular change in a variety of human body dimensions.

Many factors contribute to secular trends in anthropometric dimensions. Although the root cause of secular trends remains unknown, some of the more commonly cited possibilities are improved health, improved nutrition, changing rates of growth and maturation, assortative mating, immigration resulting in new population mixtures, immigration resulting in heterosis, changes in socioeconomic status, and changing cultural attitudes about physical fitness (Schreider, 1967; Meredith, 1976; Frisancho, 1977; Bielicki et al., 1981; Flegal et al., 1988; Lasker and Mascie-Taylor, 1989). A complication exists in that these causes generally refer to populations, groups of interbreeding individuals. The Army, however, is not a population in this sense. Instead, the Army constitutes a biased sampling of the population of the United States. The sampling bias is the result of recruiting strategies and entrance requirements. Still, because the Army is derived from the U.S. population, some of its secular trends will stem from the same root causes. However, Army trends will also be affected by changes in criteria for anthropometric standards, changes in sampling (i.e., a draft vs. an all-volunteer Army), and changes in reasons for volunteering. The manner in which each factor affects the Army population can be strongly influenced by cultural attitudes and economic conditions. The extent to which attitudes and economics cannot be anticipated and measured partially embodies the limitations of a

Received October 29, 1990; Accepted August 8, 1991.

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secular trends model. Therefore, secular trends of subgroups of the Army population do not necessarily correspond to secular trends for similar subgroups of the U.S. population.

This article reports results of an investigation of secular trends among men in the U.S. Army. The objectives were 1) to describe quantitatively the secular trends of different dimensions for several racial/cultural groups, 2) to contrast the rates of change among groups, 3) to identify the group(s) that are undergoing the greatest secular changes; and 4) to identify particular dimensions that show the greatest rates of change. The results suggest that distinctions of culture, rather than biology, may have a greater influence in contributing to observed secular change.

MATERIALS AND METHODS

The data are derived from 1966 and 1988 anthropometric surveys of U.S. Army males. A comparison of the measuring techniques in the two surveys (White and Churchill, 1971; Clauser et al., 1988) identified 22 exactly comparable dimensions. Although the 1966 survey did not collect data on race, Bradtmiller et al. (1985) outlined a method for converting data on national origin into racial identifications.[1] This method was used along with the race data collected in the 1988 survey to sort subjects into four racial/cultural groups: Whites, Blacks, Hispanics, and Asian/Pacific Islanders.

Long-term trends were quantified in each of the four groups for 22 dimensions using regression analysis. Because there are only two data sets and because a model constructed from only two values is inappropriate, the data were reorganized in order to develop meaningful models. Individuals were grouped into cohorts representing 5 year birth intervals (Table 1). This procedure divided the data from the two surveys into 13 birth-year cohorts. However, since cohorts are represented by data from both the 1966 and 1988 surveys, cohort dimensions may vary for several reasons. Among the more important reasons are 1) observer error and methodological differences, 2) age-related changes, and 3) secular trends. Because the analysis of secular trends is the crux of this investigation, the first two effects must be controlled.

Only measurements obtained through strictly comparable techniques were analyzed for secular trends. This should minimize the effects of methodological differences. The influence of observer error, however, cannot be directly controlled. Instead, information on expected observer error from the 1988 survey (Clauser et al., 1988) was used as a guide to determine the relevance of observed "secular" change. Although an observed change might be statistically significant, if it is not greater than the expected observer error it may not be meaningful.

Ideally, regression analyses should be conducted using samples of equal variance. This is, however, rarely the case in studies of secular trends. To overcome this problem, the mean value for each body dimension was calculated for each cohort, and these were submitted to regression analysis. This method is commonly used in secular change studies to overcome limitations imposed by statistical assumptions in traditional regression analyses (Trotter and Gleser, 1951a,b; Newman, 1963; Polednak, 1975; Himes and Mueller, 1977; Relethford and Lees, 1981). To accommodate very large differences in sample sizes for each cohort, the cohort mean was weighted by cohort size in the regression analyses.

Controlling for age-related changes was more complicated. Many dimensions change as a person ages (Trotter and Gleser, 1951a; Baer, 1956; Hertzog et al., 1969; Damon et al., 1972; Himes and Mueller, 1977; Borkan et al., 1983; Cline et al., 1989). Typically, the adolescent growth spurt is followed by a long period of little or no change, which is followed by a period of more rapid changes associated with senescence. The actual patterns and magnitudes of these changes vary for different dimensions. The population used in this analysis, however, is comprised of men ranging from 17 to about 50 years of age. Therefore, age-related changes need only be examined within this range. Because this age range is not associated with rapid growth or decline, age-related changes can be modeled as a straight line.

The cohorts used in this analysis vary by both age and birth-year, i.e., the same cohort

[1]During the 1966 survey soldiers were asked to identify their "ethnic derivation or national extraction" (White and Churchill 1971:33). Typical responses to this query were: American white, American Negro, Chinese, Puerto Rican, etc. Racial/cultural group identifications were made to match the 1988 survey categories by grouping national extraction responses. Thus Whites constituted all those of American white or of non-Hispanic European extraction; Blacks constituted all those of American Negro or other African extraction; Hispanics constituted all those of Spanish or Latin American extraction; and Asian/Pacific Islanders constituted all those of Asian or Pacific Island extraction.

TABLE 1. Cohort data by racial cultural group

		Whites		Blacks		Hispanics		Asian/Pacific Islanders	
Cohort	Birth years	No.	Mean age	No.	Mean age	No.	Mean age	No.	Mean age
1966 Survey data									
6	1910–1914	7	53.6	3	53.3	0		0	
7	1915–1919	7	48.7	4	48.3	3	51.0	0	
8	1920–1924	20	43.4	10	43.6	2	44.5	1	45.0
9	1925–1929	63	38.3	24	38.2	3	38.3	2	38.0
10	1930–1934	107	34.2	35	33.9	17	34.3	2	34.5
11	1935–1939	101	28.7	57	28.8	11	28.7	3	29.0
12	1940–1944	752	23.3	231	23.5	97	23.0	5	23.0
13	1945–1949	1265	19.8	385	19.7	115	19.9	19	20.0
1988 Survey data									
10	1930–1934	1	55.0	0		0		0	
11	1935–1939	0		3	50.7	2	50.0	3	50.3
12	1940–1944	15	45.6	13	45.0	15	44.9	17	45.3
13	1945–1949	97	40.3	62	40.5	48	40.5	43	40.8
14	1950–1954	171	36.0	151	35.9	120	35.5	72	35.5
15	1955–1959	241	30.9	252	20.9	183	30.8	91	30.8
16	1960–1964	406	25.8	356	25.9	257	25.9	101	25.9
17	1965–1969	753	20.7	646	20.7	418	20.8	118	21.1
18	1970–1974	53	17.9	36	17.8	21	18.0	5	18.0

drawn from the two surveys will represent different age groups. Therefore, the relationship between dimension and cohort is influenced by both age and secular changes. A plot of chest circumference versus cohort (Fig. 1) best illustrates this pattern. This example and Table 1 show that the two surveys overlap by four cohorts. Because a cohort represents persons born in a specific interval of years, the observed difference in values between a cohort in 1966 and the same cohort in 1988 should be because of age at the time of measurement. This difference can be read as the change due to age in a 22 year period. Multiplying this value by 5/22 converts it into the rate of age-related change per 5 year cohort. This creates a two-point linear model of age-related change. As many as 20 such models, one for each birth-year in the four overlapping cohorts, were generated in this manner for each dimension in each racial/cultural group. The inherent weakness of a two-point linear model was addressed by using the mean value of the slopes of these models for each dimension within a racial/cultural group as the best estimate of the rate of change due to aging (Hyde, 1980). Rates of age-related change calculated in this fashion are comparable with previously reported values (Cline et al., 1989).

Mean rates of age-related change were used to control for the effects of age within each cohort. The age of 20 years was chosen to represent the age of maximum expression for anthropometric dimensions.[2] Deviations from this age were then adjusted to control for age-related effects (Relethford and Lees, 1981; Borkan et al., 1983). Assuming that anthropometric dimensions reach a maximum or mature value at age 20 years, age-adjusted values were calculated for each dimension according to the following equation:

$$AAV = V - AF\{[(Y - 1900)/5] - C\}.$$

In this equation AAV is the age-adjusted value; V is the observed anthropometric value; AF is the age correction factor; Y is the survey year rounded down to 5 year intervals; and C is the birth-year cohort. The term (Y − 1900)/5 represents the birth-year cohort that would include 20 year olds for the

[2]The age of 20 years was chosen for two reasons. First, as the Army is composed primarily of young people, the cohort that contains 20 year olds will tend to be the most, or second most, populous cohort. Therefore, this cohort was selected as the most "typical." Second, previous studies (Trotter and Gleser, 1951a,b; Borkan et al., 1983) show an increasing maturation rate within the U.S. population. This would result in maximum growth being attained by younger persons, which has been used as an explanation of some observed secular trends. Because of this, some studies choose the age of 30 years to represent the age of maximum growth (Trotter and Gleser, 1951a; Relethford and Lees, 1981; McCullough, 1982). These studies, however, do not investigate modern American populations. Current populations attain maximum growth at a younger age (Annis, 1978; Bradtmiller et al. 1985). Therefore, it is appropriate to choose the age of 20 years as the age of maximum growth.

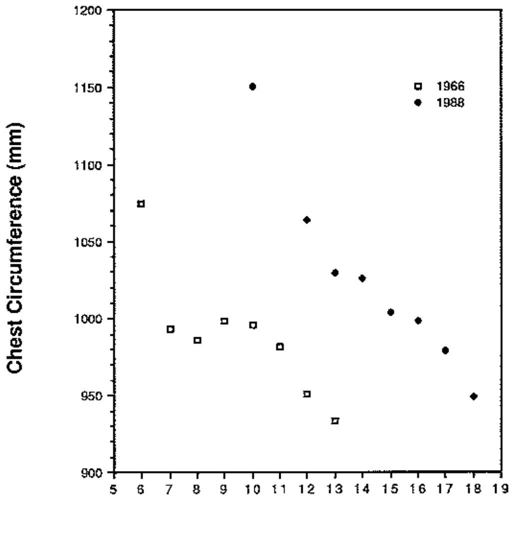

Fig. 1. Plot of measured chest circumference of Whites versus birth-year cohort (time) without adjustments for age-related effects. Note that the scatter plot shows an apparent negative trend in the two roughly parallel lines formed by the 1966 and 1988 data sets.

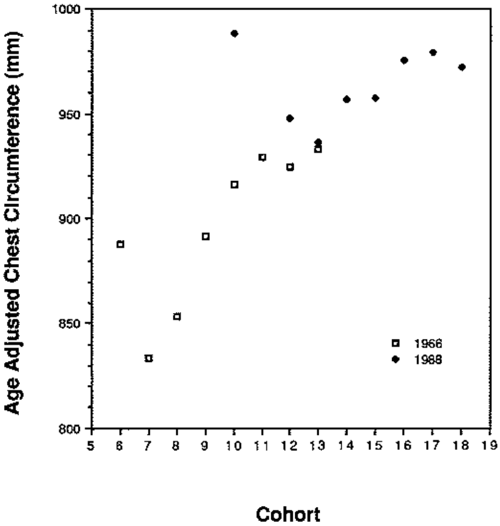

Fig. 2. Plot of age-adjusted chest circumference of Whites versus birth-year cohort (time). Note that the scatter plot now shows a strong positive trend and that the two data sets can easily be linked to form a single curve.

year Y. Figure 2, which is a plot of age-adjusted values for chest circumference versus cohort, shows the results of this transformation.

The age-related adjustments have an additional benefit of controlling population variations between the 1966 and 1988 surveys. A common cultural attitude in our society is that military service represents a means of achieving a higher socioeconomic standing. If this is true, changes in body dimensions would be most pronounced during the transition from the civilian to the Army population. Any residual changes due to this shift would be partly responsible for measurement differences in the same cohort drawn from the two survey data bases. Therefore, these changes would act as if they were age related and would be controlled by the age adjustment process. In addition, any changes in the Army's height and weight maintenance requirements between 1966 and 1988 would also appear to be age-related changes and would be similarly controlled. Presumably, therefore, the remaining minor differences between two age-adjusted values for the same cohort are the results of uncontrollable sampling and observer error.

Secular trends were studied by regressing the age-adjusted dimensions with cohort. These bivariate regressions produce the following generic equation:

$$\text{Age Adjusted Value} = a\ \text{Cohort} + b.$$

In this linear equation, b is the y-intercept constant and a is the slope of the line. Because the equation describes the relationship between cohort (time) and an anthropometric dimension controlled for non-secular influences, the term a is read as the rate of secular change.

Rates of secular change were compared between racial/cultural groups by testing equality of regression slopes with SPSS analysis of covariance software. Slope comparisons that had low F values and significance levels greater than 0.05, corrected for 11 simultaneous comparisons of group combinations, were not considered to be statistically different. This information was used to determine which groups were undergoing markedly different trends for specific dimensions.

Discriminant analysis was then used to determine which dimensions were undergoing the most relative change. This analysis was conducted by using the age-adjusted

TABLE 2. Secular trend rates within racial/cultural groups

Dimension	Whites	Hispanics	Blacks	Asian/Pacific Islanders
Weight	1.36	1.44	0.74	−0.13*
Stature	3.71	5.08	1.46	−5.64
Neck circumference	0.59	0.23	−0.57	−0.72
Chest circumference	10.69	10.54	7.33	2.26
Calf height	−0.26	−0.82	−0.48	−1.53
Calf circumference	2.61	2.51	1.72	0.83
Crotch height	0.32	−0.48	0.77	−3.88
Sitting height	3.57	4.15	3.21	−0.42
Forearm-hand length	0.99	1.56	−0.09	−0.51
Knee height, sitting	4.63	4.03	3.55	−0.06*
Bideltoid breadth	8.54	8.39	6.63	6.27
Chest breadth	3.78	4.55	0.97	1.43
Hip breadth, sitting	5.41	6.37	4.77	3.46
Thumbtip reach	−6.53	−5.29	−8.28	−8.11
Head length	0.51	0.79	0.03	0.89
Head circumference	0.54	1.69	0.54	2.11
Head breadth	−0.27	−0.21	−0.18	−0.14
Bizygomatic breadth	−0.11	−0.05	−0.05	0.05*
Ankle circumference	−0.75	−0.81	−1.19	−2.67
Foot length	0.71	0.82	−0.13	−0.92
Hand length	0.98	0.86	0.40	0.44
Hand breadth	0.44	0.40	0.25	−0.09

Values are presented in millimeters per cohort, except for weight, which is presented in kilograms per cohort. Trends marked with an asterisk are not significantly different from zero ($P > .05$) corrected for 22 simultaneous comparisons. Trend values linked by underlining are not significantly different ($P > .05$) among groups, corrected for 11 simultaneous comparisons.

dimensions to discriminate between the 1966 and 1988 survey populations. Those dimensions that showed the highest within-group correlations were identified as having changed the most. Patterns of change were then compared by repeating this analysis for each racial/cultural group.

RESULTS

Table 2 presents rates of secular change revealed by the relationships between birth-year cohort and the anthropometric dimensions; statistical details on the regression models for each dimension within each racial/cultural group are presented in the Appendixes A–D. Several trends, all associated with Asian/Pacific Islanders, are not significantly different from zero. This lack of relationship implies that the dimensions are not undergoing a significant secular trend. Early exploration of the data suggests that rates of change many be decreasing for some dimensions, although significant slopes were observed. In these dimensions secular change may no longer be occurring or is occurring at a greatly reduced rate. All dimensions were also explored using nonlinear regression techniques. In no instance, however, were models markedly improved, as judged by correlation coefficients and standard errors. Therefore, linear models were retained for all dimensions.

Table 3 shows results of the discriminant analyses. Dimensions that had the highest within-group correlations were judged to have undergone the most secular change. The analysis was first used to test the entire sample of pooled races to determine the baseline pattern of change for the entire population. In the test of pooled races, measurements related to soft tissues (i.e., muscle and fat) were most highly correlated with discrimination, whereas skeletal dimensions, such as stature and head breadth, were poorly correlated with discrimination. This pattern was, for the most part, reflected in the results of separate discriminant analyses of each group.

Explanations for some secular trends were found in the immigration patterns (Table 4). These patterns were evaluated using a Mantel-Haenszel chi-squared test (Mantel, 1963) of the linear relationship between birth-year and birthplace (U.S. vs. non-U.S.). Adjacent cohorts were pooled in these analyses to avoid sparse cells that would compromise the validity of the Mantel-Haenszel test. Cells were scored according to the median birth-year of their membership. These tests showed no significant trend in the immigra-

TABLE 3. Within-group correlations between age-adjusted body dimensions and discriminant function

Dimension	Pooled races	Whites	Blacks	Hispanics	Asian/Pacific Islanders
Bideltoid breadth	−0.438	−0.224	−0.097	0.095	−0.050
Chest circumference	−0.363	−0.204	−0.074	0.131	−0.036
Hip breadth, sitting	−0.363	−0.150	−0.078	0.079	−0.124
Chest breadth	−0.346	−0.202	−0.058	0.127	−0.056
Calf circumference	−0.241	−0.140	−0.119	0.089	−0.001
Weight	−0.214	−0.183	−0.040	0.095	0.001
Thumbtip reach	0.207	0.059	0.053	0.004	0.159
Knee height, sitting	−0.186	−0.184	−0.058	0.071	0.043
Hand breadth	−0.165	−0.091	−0.055	0.056	0.016
Head circumference	−0.143	−0.049	−0.062	0.045	−0.249
Sitting height	−0.140	−0.087	−0.059	0.069	−0.023
Hand length	−0.128	−0.134	−0.019	0.073	0.002
Ankle circumference	0.090	−0.029	0.006	−0.001	0.061
Calf height	0.085	−0.036	0.059	−0.020	0.042
Head length	−0.080	−0.045	−0.035	0.098	−0.287
Foot length	−0.058	−0.101	0.004	0.081	0.034
Stature	−0.048	−0.132	−0.001	0.053	0.060
Bizygomatic breadth	−0.037	−0.074	0.014	−0.029	−0.164
Crotch height	0.021	−0.072	0.010	0.008	0.149
Neck circumference	0.013	−0.180	−0.028	0.034	−0.019
Forearm-hand length	−0.013	−0.090	0.024	0.053	0.060
Head breadth	0.003	−0.135	0.003	0.002	−0.133

tion pattern of Whites. Blacks and Hispanics showed significant patterns of linear increase in the number of non-U.S.-born members, but these groups are still primarily comprised of native-born Americans. Therefore, the effects of immigration may not be strong enough to have had a large influence on secular change patterns. Asian/Pacific Islanders are primarily comprised of non-U.S.-born members, and the test shows a pattern of significant linear increase in immigration rates within this group.

DISCUSSION

Military service populations are often thought of as oversampling lower socioeconomic sectors of society. If this is true, many investigators might look to an associated improvement in socioeconomic status as a cause of secular trends. Invoking this socioeconomic shift as a cause for secular trends is inappropriate for this investigation, since all persons examined here are part of the Army population. Any shifts that might occur due to changes in socioeconomic status during the transition from a civilian to a military population are therefore irrelevant to this investigation. Changes in socioeconomic status would only influence secular trends if there were significant changes within the Army population. Although socioeconomic status is difficult to measure, we would expect its change to be associated with a substantial difference in the diets and relative pay scales for the 1966 and 1988 Army populations. There is no evidence of such differences (although they would be almost certainly true in a longer term analysis). Therefore, it seems safe to state that the socioeconomic status of a soldier, especially soldiers within a racial/cultural group, has remained unchanged.

The presented secular trends can be seen as the consequence of two root causes. First is a change in the expression of genetic potential, which may be due to the introduction of new genetic admixture through immigration or the influence of changes in health and nutrition levels during growth. Second is the alteration of body dimensions dictated by cultural ideals, which may be brought about through changes in diet and exercise. Although these two factors can, and certainly do, interact, changes in genetic potential should be more pervasive and therefore more evident in the skeletal dimensions. Levels of health and nutrition will have their greatest influence during periods of growth (Bogin, 1988). This may effect the dimensions of adult populations through a lifetime expression of childhood deprivation. Thus, the influence of genetic potential sets a template for adult skeletal dimensions that cannot be changed through later cultural practices.

Soft tissue dimensions, however, are very susceptible to change. Although these di-

TABLE 4. Evaluation of immigration patterns

	Whites: median birth-year						
Birthplace	1930	1943	1946	1951	1956	1961	1967
U.S.	204[a]	832	1318	164	228	388	770
	198.1[b]	838.6	1315.8	165.2	232.8	392.2	761.2
Non-U.S.	1	36	44	7	13	18	18
	7.0	29.4	46.2	5.8	8.2	13.8	26.7

Mantel-Haensel chi-squared = 0.008; d.f. = 1; $P = .931$.

	Blacks: median birth-year				
Birthplace	1941	1946	1955	1961	1967
U.S.	378	443	387	344	661
	370.8	436.2	393.4	347.4	665.5
Non-U.S.	2	4	16	12	21
	9.2	10.8	9.8	8.6	16.5

Mantel-Haensel chi-squared = 10.660; d.f. = 1; $P = .001$.

	Hispanics: median birth-year					
Birthplace	1943	1946	1952	1956	1961	1966
U.S.	56	88	61	86	141	303
	84.0	91.3	67.2	102.5	144.0	245.9
Non-U.S.	94	75	59	97	116	136
	66.0	71.7	52.8	80.5	113.0	193.1

Mantel-Haensel chi-squared = 42.231; d.f. = 1; $P = .000$.

	Asian/Pacific Islanders: median birth-year					
Birthplace	1942	1946	1952	1957	1961	1966
U.S.	16	21	14	12	22	33
	8.1	15.2	17.6	22.3	24.7	30.1
Non-U.S.	17	41	58	79	79	90
	24.9	46.8	54.4	68.7	76.3	92.9

Mantel-Haensel chi-squared = 4.270; d.f. = 1; $P = .039$.

[a]Observed.
[b]Expected.

mensions would be responsive to genetic influences during childhood and adolescence, only soft tissue dimensions would be expected to change in adult populations as the result of cultural practices. In this way, relative rates of change in soft tissue versus skeletal dimensions can be used as an indicator of the primary influence in secular trend patterns. Those populations characterized by high rates of change in skeletal dimensions would be responding to changes in population mixtures or to the factors that influence growth. Similarly, those populations characterized by high rates of change in soft tissue dimensions would be responding more to cultural influences that can affect adult body dimensions. Greater rates of change in soft tissue dimensions over skeletal dimensions are not what would be expected as the result of increased genetic expression through improved health and nutrition. These patterns of change, however, would be expected as the result of the recent cultural emphasis on physical fitness and the "ideal" body (Polednak, 1975; Takahashi, 1986).

Whites showed significant rates of change in all body dimensions. The estimated rate of secular change for stature (3.71 mm per cohort or 0.7 cm per decade) is comparable to the commonly reported rate of 0.6 cm per decade (Bradtmiller et al., 1985; Annis, 1978). These results are contrary to some studies (Bawkin and McLaughlin, 1964; Damon, 1968) that show a slowing or cessation of secular trends of skeletal dimensions such as stature in Whites. Those studies primarily focus on college students, who generally represent members of the highest socioeconomic levels of American society. Presumably subjects in these studies developed in a sociocultural environment that permitted growth to reach its genetic potential. However, military personnel are not limited to these levels of society and thus may not be expressing their genetic potential. Therefore, a pattern of continued secular trends in the skeletal dimensions in more diverse populations of whites is not unexpected and has been documented in other studies (Bock and Sykes, 1989).

General trend patterns for the pooled racial/cultural groups are associated with higher rates of change in soft tissue dimensions. This pattern is consistent with an interpretation that cultural ideals, associated with physical fitness, health, and diet fads, comprise the main stimuli for observed secular trends. This general pattern is most closely replicated by Whites, which would be expected since Whites are the largest group and can be said to drive patterns of change. Whites can therefore set a pattern for comparison with the other groups.

The observed trends of Hispanics tend to mirror the patterns of whites, but at a lower rate. The trend rates of Hispanics, however, generally fall between the rates of Whites and the rates of Blacks. There are several possible explanations for this phenomenon. First, Hispanics could be considered as a racial subgroup of Whites, one that is typified by slightly smaller anthropometric dimensions. Therefore, the lower trend rates of Hispanics may be showing the same pattern as Whites, but at a lower rate because of smaller overall size. Thus rates of change, if interpreted as a percentage change per unit time, might be viewed as being more comparable between the two groups. Second, Hispanics in the Army are comprised of a large portion (44%) of non-American-born members, although most of these persons have consistently come from Mexico and Puerto Rico (6.6% Mexico, 26.5% Puerto Rico, 56% United States, 10.8% other). If the proportion of Mexican and Puerto Rican–born Hispanics remained constant, the perceived influence of migration on this racial/cultural group would be minimal. In this instance, migration would lessen the effects of cultural influences relative to Whites without changing the group's character. However, there is a small, but statistically significant, increase in the foreign-born membership of the Hispanic group (Table 4). This gradual increase of immigrants from other nations may be changing the character of secular change in Hispanics. The effects of this change, however, may not yet have accumulated to the extent that they override culturally determined patterns of change. Third, as a distinct cultural group, cultural fashions that effect secular trends in Whites may not have been fully assimilated by Hispanics.

Blacks showed the lowest rates of secular change, while still roughly paralleling the pattern of change associated with soft tissue over skeletal dimensions. Generally, the explanations associated with Hispanics can also explain the differences between the patterns of Whites and Blacks. Although Blacks also show a significant linear increase in immigration (Table 4), this group is overwhelmingly comprised (97.6%) of native-born Americans. Therefore, it is not reasonable to invoke immigration as an explanation for these secular trend patterns. Massey and Denton (1989) show that in American society Blacks are more segregated from the main population than are Hispanics. Because Blacks have been more isolated from society's resources, their secular change patterns might be more sensitive to changes in levels of health and nutrition. The effects of this source of change may be evidenced by the higher correlation of skeletal dimensions to the discriminant function (Table 3). Perhaps the best explanation for this pattern is that as a consequence of societal segregation Blacks would be furthest removed, and least motivated, by the cultural ideals of Whites.

Asian/Pacific Islanders stand out as the only group that showed a completely unique pattern of secular trends. The correlations of Asian/Pacific Islanders mirrored the general trend of decreasing anthropometric dimensions with the greatest emphasis on skeletal, rather than soft tissue, dimensions. This suggests that this population is responding to a change in genetic potential (Damon, 1968; Schreider, 1967). The source of this genetic change is best explained as the result of immigration.

Asian/Pacific Islanders underwent a dramatic shift in their makeup between the 1966 and 1988 surveys. In 1966 this group was comprised primarily of native-born Americans with the modal segment identifying itself with Japanese ancestry. In 1988 this group was comprised primarily of foreign-born Americans with the majority being born in the Philippines. In the total group only 24.5% of the Asian/Pacific Islanders were native-born Americans. Thus the significant linear increase in immigration (Table 4) can be seen as the driving force for the secular trend pattern of this group. The shift in this population from nonindustrialized nations, such as the Philippines, to the United States would be accompanied by improved health and nutrition. Therefore, this group follows the expected pattern by having skeletal dimensions most highly correlated with the secular change discriminant function (Table 3). Asian/Pacific Islander thus exemplify a biologically defined group that contains broad cultural distinctions.

In general, statistically significant rates of change were detected in each group for every dimension, the exceptions being associated with Asian/Pacific Islanders. Nevertheless, the biological importance of these changes is unclear. For all dimensions, the magnitude of change was very small—most were less than 1 cm per decade. The causes of these changes seem to relate to cultural processes; either conforming to a culturally ideal body type, culturally determined access to resources, or the socioeconomic forces that compel migration. Although the Army outlines weight to height restrictions (Army Regulation 40-501, 1989), these regulations are not as strict as is commonly believed, and they are not uniformly enforced. Therefore, these regulations might truncate the tails of a population distribution but would not greatly influence the population means. The idealized body type of the Army might differ from that of the population at large, but that ideal is still culturally defined. Although the Army has always promoted physical fitness, there has to be an attitudinal shift for those changes to take hold. This shift in attitude about physical fitness may have started earlier in the Army, but it still reflects the attitude of the general population. These conclusions suggest that biological forces play a diminished role in shaping secular trend patterns. The identification of "racial" groups implies a biological distinction, yet the cultural differences within biological groups cannot be dismissed. Therefore, in future studies of secular trends, it may be paramount to consider the cultural distinctions within and among groups before biological differences are explored.

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Appendix A: Models for Whites

Dimension	Constant (b)	Secular trend (a)	Age factor (AF)	SEE	R
Weight	53.55	1.36	2.85	0.74	.94
Stature	1700	3.71	3.54	5.11	.72
Neck circumference	365.9	0.59	2.86	2.50	.21
Chest circumference	796.3	10.78	23.25	6.00	.94
Calf height	354.4	−0.27	−0.68	1.57	.12
Calf circumference	331.8	2.67	4.35	2.41	.86
Crotch height	829.3	0.46	−1.12	4.21	.05
Sitting height	863.6	3.57	5.14	3.50	.83
Forearm-hand length	463.1	0.99	1.46	1.88	.57
Knee height, sitting	478.2	4.68	4.35	2.07	.96
Bideltoid breadth	343.5	8.54	9.41	3.77	.96
Chest breadth	254.9	3.78	7.79	2.01	.94
Hip breadth, sitting	273.1	5.41	8.01	1.94	.97
Thumbtip reach	905.8	−6.53	−2.71	4.98	.89
Head length	188.6	0.51	0.43	0.96	.57
Head circumference	557.5	0.52	−0.02	3.42	.10
Head breadth	154.8	−0.25	0.77	0.79	.32
Bizygomatic breadth	140.2	−0.09	0.91	0.09	.09
Ankle circumference	235.4	−0.71	0.04	1.98	.38
Foot length	256.0	0.71	1.19	0.99	.71
Hand length	175.3	0.98	1.51	0.80	.88
Hand breadth	82.53	0.46	0.89	0.66	.69

All regression values are significantly different from zero ($P < .05$) when corrected for 22 simultaneous comparisons.

Appendix B: Models for Blacks

Dimension	Constant (b)	Secular trend (a)	Age factor (AF)	SEE	R
Weight	63.56	0.77	2.11	1.74	.48
Stature	1732	1.46	−1.19	5.86	.23
Neck circumference	389.4	−0.66	0.87	3.24	.17
Chest circumference	835.1	7.48	18.89	9.68	.74
Calf height	382.8	−0.76	−2.20	2.87	.25
Calf circumference	347.2	1.69	2.80	3.30	.57
Crotch height	855.7	0.44	−4.77	4.10	.05
Sitting height	835.6	3.21	2.39	3.54	.80
Forearm–hand length	502.6	−0.22	−0.18	1.79	.07
Knee height, sitting	509.6	3.55	2.87	2.30	.92
Bideltoid breadth	376.4	6.63	7.71	5.63	.87
Chest breadth	290.7	0.97	4.58	3.65	.25
Hip breadth, sitting	274.9	4.77	6.98	4.83	.82
Thumbtip reach	959.6	−8.34	−7.89	3.46	.97
Head length	196.7	0.03	0.53	0.51	.02
Head circumference	557.3	0.54	2.36	1.38	.42
Head breadth	153.4	−0.17	0.41	0.56	.30
Bizygomatic breadth	141.1	−0.05	0.56	0.84	.02
Ankle circumference	241.1	−1.28	−0.76	1.38	.80
Foot length	275.0	0.06	−0.10	1.04	.01
Hand length	192.0	0.40	1.16	0.71	.60
Hand breadth	86.34	0.25	0.84	0.45	.61

All regression values are significantly different from zero ($P < .05$) when corrected for 22 simultaneous comparisons.

Appendix C: Models for Hispanics

Dimension	Constant (b)	Secular trend (a)	Age factor (AF)	SEE	R
Weight	49.50	1.44	2.29	1.32	.82
Stature	1622	5.34	2.77	7.60	.65
Neck circumference	369.0	0.22	2.06	2.90	.02
Chest circumference	792.4	10.74	20.57	8.66	.85
Calf height	357.3	−0.70	−2.58	2.66	.21
Calf circumference	329.7	2.51	1.83	3.95	.60
Crotch height	816.0	−0.26	−5.84	3.90	.02
Sitting height	823.8	4.27	4.91	5.07	.85
Forearm–hand length	450.1	1.27	0.05	2.70	.45
Knee height, sitting	475.3	4.09	2.46	2.60	.90
Bideltoid breadth	344.0	8.39	8.87	3.88	.95
Chest breadth	239.2	4.63	8.42	2.51	.93
Hip breadth, sitting	252.4	6.37	8.38	2.47	.96
Thumbtip reach	869.9	−5.29	−5.80	4.74	.82
Head length	180.2	0.79	0.75	0.79	.79
Head circumference	533.9	1.69	2.56	1.32	.86
Head breadth	155.1	−0.18	0.54	0.51	.32
Bizygomatic breadth	141.6	−0.05	0.53	0.77	.02
Ankle circumference	232.6	−0.81	−1.52	1.28	.60
Foot length	251.1	0.82	−0.02	1.35	.58
Hand length	173.2	0.91	0.97	1.03	.75
Hand breadth	80.84	0.44	0.56	0.43	.80

All regression values are significantly different from zero ($P < .05$) when corrected for 22 simultaneous comparisons.

Appendix D: Models for Asian/Pacific Islanders

Dimension	Constant (b)	Secular trend (a)	Age factor (AF)	SEE	R
Weight	74.18	−0.13	0.43	1.95	.01
Stature	1791	−5.64	−8.87	12.31	.38
Neck circumference	381.6	−0.72	1.07	3.47	.11
Chest circumference	907.5	2.26	8.36	11.46	.10
Calf height	355.1	−1.53	−2.13	4.58	.25
Calf circumference	366.4	0.83	1.36	4.34	.10
Crotch height	858.2	−3.88	−7.67	5.64	.58
Sitting height	908.4	−0.42	−0.43	7.14	.01
Forearm–hand length	473.2	−0.51	−1.02	3.68	.05
Knee height, sitting	531.5	−0.06	−1.51	4.09	.00
Bideltoid breadth	378.3	6.27	6.04	4.07	.87
Chest breadth	283.5	1.43	4.29	3.84	.29
Hip breadth, sitting	295.7	3.46	5.54	4.50	.63
Thumbtip reach	902.5	−8.11	−8.04	3.79	.93
Head length	175.7	0.89	0.75	1.45	.52
Head circumference	524.8	2.11	2.82	3.75	.48
Head breadth	157.1	−0.14	0.49	1.04	.05
Bizygomatic breadth	143.7	0.05	0.77	0.90	.01
Ankle circumference	264.5	−2.67	−3.35	1.99	.84
Foot length	276.9	−0.92	−2.32	2.88	.23
Hand length	180.7	0.44	0.28	1.82	.15
Hand breadth	89.99	−0.09	−0.31	0.95	.02

All regression values are significantly different from zero ($P < .05$) when corrected for 22 simultaneous comparisons, with the following exceptions: weight, $P = .011$; knee height, sitting, $P = .556$; and bizygomatic breadth, $P = .023$.