ORIGINAL COMMUNICATIONS

HEART RATE OF BLACK AND WHITE YOUTHS AGED 12–17 YEARS:

Associations With Blood Pressure and Other Cardiovascular Risk Factors

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Correlates of heart rate were investigated in youths aged 12 to 17 years examined in the United States National Health Examination Survey. Heart rate decreased with age in boys but no consistent trend appeared in girls. Girls had higher heart rates than boys. Blacks had heart rates 6 to 12 beats per minute lower than whites of the same age and sex.

Multiple regression analysis showed the effect of race to be independent of multiple other variables. Regression analyses within sex-race groups identified the following independent correlates of heart rate: white boys, age, systolic blood pressure, and body temperature; black boys, age, body temperature, subscapular skinfold, and systolic blood pressure; white girls, systolic blood pressure, body temperature, cigarette smoking; black girls, body temperature. Correlations of two heart rate measurements 28 to 53 months apart (median 44 months) ranged from $r = 0.21$ to $r = 0.30$.

Although expanded blood volume and lower sympathetic tone in blacks have been hypothesized, further longitudinal studies are needed to explain the differences in heart rates between races and sexes and their relationship to hypertension in adulthood.

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Elevated heart rate is a risk factor for hypertension and for cardiovascular and all-cause mortality.[1,2] Despite a higher risk of hypertension and cardiovascular mortality, blacks have been reported to have lower resting heart rates compared with whites among children and young adults, with no consistent racial differences over the age of 35 years.[3-6] Published data are few on the heart rate of adolescents from geographically defined populations. Therefore, data on a large sample of youths drawn from the United States population aged 12 to 17 years were examined for racial differences in heart rate and for correlates of heart rate.

METHODS

The third cycle of the National Health Examination Survey (HES) was conducted on a nationwide multistage probability sample of 7,514 youths from the noninstitutionalized population of the United States aged 12 to 17 years. This survey started in March 1966, and ran until March 1970. Of the 7,514 youths selected for the sample, 6,768 (90 percent) were examined. There were 5,735 whites, 999 blacks, and 34 others. Details of the plan, sampling, response, and operation were published previously, as were procedures for obtaining informed consent and maintaining confidentiality of data.[7]

Demographic, medical history, and behavioral information was collected by household interview and self-administered questionnaires prior to the examination. Conducted in a mobile center, the examination included a pediatrician's assessment of breast development stage in girls, male genital development stage in boys, and pubic hair stage in both sexes.[8] A nurse measured blood pressure supine at the beginning and at the end of a physician's examination using a mercury sphygmomanometer as described in detail elsewhere.[9] The average of these readings was used in the present analysis.

In the HES, diastolic pressure was defined as the complete cessation of sounds. If the sounds failed to disappear, the pressure at which muffling occurred was used. A pediatric or adult cuff was used as appropriate. Heart rate was measured from an electrocardiogram monitor strip containing 15 to 20 clear complexes taken with the subject standing quietly prior to a five-minute treadmill exercise test.[7] Electrocardiograms (ECGs) were recorded again at the end of the test, for the five-minute pulse rate.

The grade of the treadmill was 0 degrees for the first two minutes and was raised to 10 degrees for the last three minutes of the test. The calibrated treadmill speed was 3.5 mph for the entire test. The subject was instructed to walk naturally with hips straight, head up, and arms swinging. ECG measurements were made by an expert consultant. Room temperature was maintained at 70 to 74 °F and relative humidity was maintained at 50 to 60 percent during the exercise test. Hand grip strength was also determined.[7]

A blood sample was taken and sent to the laboratories of the Center for Communicable Diseases in Atlanta, for analyses of levels of total serum cholesterol by the Abell-Kendall method,[10] serum uric acid by the Technicon auto-analyzer-1 (N-136 method), a calorimetric phosphotungstate procedure,[11] and for protein bound iodine determination as described elsewhere.[12] Technicians performed x-ray examinations of the hand and wrist for assessment of bone age and measured weight to the nearest pound, standing height to the nearest centimeter, and waist and hip and girths and subscapular skinfold thickness to the nearest millimeter.[13] Before the examination, body temperature was measured to the nearest 0.1 °F with an oral thermometer. Any examinee with a temperature of 100 °F or over could be sent home and rescheduled for another date at the physician's discretion.

The Health Examination Survey Cycle III of youths was based on the same sample design as the previous survey of children aged 6 to 11 years.[14] Since the same sampling areas and households were used, nearly one third of the youths examined in Cycle III had also been examined in the earlier Cycle II Survey of Children. Cycle II was conducted from 1963 to 1965. The time lapse between the two examinations of the same sample person ranged from 28 months to five years. In the present analyses, only subjects with follow-up times of 28 to 53 months (median 44 months) were included. Methods used in the earlier examination were similar to those described above. Resting pulse rate was measured with the child supine. A nurse took two blood pressure readings in the right arm supine with a mercury sphygmomanometer as described in detail.[15] The average of these was used in the present analysis. Technicians measured height to the nearest millimeter, weight to the nearest half-pound, and a series of body measurements including standing waist and hip girth and subscapular skinfold thickness to the nearest millimeter.[16] An x-ray film of the right hand and wrist was taken for determination of skeletal age as described elsewhere.[17]

Population estimates for most of the variables other than heart rate have been published by the National Center for Health Statistics* in the form of Series 11 reports.[9-13,16,17] Data in the paper were not weighted to give precise estimates for the United States population. However, the sample was large and quite like the population in most demographic characteristics.[7] Furthermore, the subsample examined at two times resembles the overall sample for most characteristics as described elsewhere.[18] All descriptive statistics were computed by standard methods using unweighted data. Pearson product moment correlation was used to assess the association of heart rate with other continuous variables. Kendall's nonparametric rank correlation was used to assess the association of heart rate with ordinal variables and to assess tracking of

* Most publications of the National Center for Health Statistics are available in libraries. Recent publications can be ordered from the Division of Data Services at the address listed below or from the Superintendent of Documents, US Government Printing Office, Washington, DC, 20402, (202) 783-3238. A catalog of currently available publications can be ordered from the Scientific and Technical Information Branch, Division of Data Services, National Center for Health Statistics, 3700 East West Highway, Hyattsville, MD 20782, (301) 436-8500.

TABLE 1. HEART RATE OF YOUTHS BY AGE, SEX AND RACE, NATIONAL HEALTH EXAMINATION SURVEY

	Boys			Girls		
Age (years)/Race	**Mean**	**Standard Error**	**No.**	**Mean**	**Standard Error**	**No.**
12						
White	89.45	0.67	512	99.44	0.82	426
Black	80.68	1.33	99	87.94	1.80	80
13						
White	87.55	0.68	505	97.21	0.82	453
Black	81.87	1.63	77	88.42	1.73	83
14						
White	87.24	0.67	505	96.32	0.84	447
Black	77.79	1.47	84	89.91	1.57	91
15						
White	85.58	0.71	499	97.28	0.91	397
Black	77.04	1.76	78	85.44	1.83	66
16						
White	83.86	0.74	466	95.85	0.83	406
Black	74.38	1.64	53	87.39	1.93	79
17						
White	82.06	0.80	376	96.73	0.88	342
Black	72.47	1.65	57	83.63	1.69	57
18*						
White	—	—	22	—	—	17
Black	—	—	8	—	—	7

* Values not given owing to small numbers; these subjects aged 17 at sample enumeration but 18 by the time of examination are grouped with 17-year-olds in other analyses.

rank for pulse rate between the two examinations.[19] Linear multiple regression analysis was used to compute adjusted mean heart rates for each sex race group. Stepwise linear multiple regression (SAS MAX R) analysis was used to develop models for predicting resting heart rate for each sex race group in Cycle III and for identifying independent correlates of Cycle III heart rate from Cycle II measurements.[20] Only variables with statistically significant bivariate correlation coefficients were eligible to enter the model.

RESULTS

The mean heart rates by age, sex, and race are shown in Table 1. Heart rate decreased with age in boys. Changes in girls were less consistent. At each age, black boys and girls had substantially lower mean heart rates compared with their white counterparts. Similar racial differences were also seen within the four regions of the United States. Girls consistently had higher heart rates than boys for both races.

The double product of mean blood pressure times heart rate was computed from heart rate and mean blood pressure: [systolic + (2 × diastolic)]/3. This formula was used to enable comparisons to be made with other published data.[6] Whites had higher values at each age for both sexes compared with blacks. Overall means were white boys 7,994 (standard deviation 1,737), black boys 7,184 (SD 1,508), white girls 8,925 (SD 1,955), and black girls 8,008 (SD 1,630) mmHg–beats per minute.

The pattern varied among sex race groups for correlations of heart rate with other variables (Table 2). Inspection of scatter plots of heart rate with blood pressure and other variables by sex-race group did not suggest nonlinear relationships with the exception of a possible U-shaped relationship of heart rate with subscapular skinfold in boys. A number of heart rates above 100 beats per minute occurred in boys with skinfolds less than 10 mm; a consistent positive relationship held between 10 and 48 mm.

Within single-year age groups, heart rate was not

TABLE 2. PEARSON CORRELATION COEFFICIENTS AND STATISTICAL SIGNIFICANCE LEVELS FOR HEART RATE WITH OTHER VARIABLES

	Black boys		White boys		Black girls		White girls	
Variable	*r*	P	*r*	P	*r*	P	*r*	P
Age (months)	−0.22	.00	−0.16	.00	−0.08	.08	−0.05	−.02
Height (cm)	−0.16	.00	−0.08	.00	0.04	.40	0.01	.64
Weight (kg)	−0.08	.08	−0.02	.27	0.05	.30	0.03	.15
Body mass index (kg/m^2)	0.00	.93	0.03	.14	0.03	.50	0.03	.13
Ponderal index (in./lb^3)	−0.06	.22	−0.05	.01	−0.00	.92	0.01	.56
Subscapular skinfold (mm)	0.14	.00	0.12	.00	0.05	.28	0.07	.00
Waist-to-hip ratio	0.06	.17	0.07	.00	0.03	.56	−0.01	.53
Systolic BP	0.07	.16	0.09	.00	0.06	.17	0.20	.00
Diastolic BP	−0.04	.33	0.03	.06	0.01	.75	0.15	.00
Serum uric acid (mg/dL)	−0.02	.68	0.01	.33	0.08	.10	0.05	.01
Serum cholesterol (mg/dL)	0.04	.39	0.10	.00	−0.01	.81	0.08	.00
Hematocrit (%)	−0.13	.01	−0.01	.42	0.04	.34	0.09	.00
5-Minute exercise pulse	0.51	.00	0.53	.00	0.32	.00	0.42	.00
Change in pulse with exercise	−0.31	.00	−0.38	.00	−0.67	.00	−0.70	.00
Log (pulse 5/pulse 0)	−0.76	.00	−0.76	.00	−0.88	.00	−0.89	.00
Temperature	0.28	.00	0.17	.00	0.29	.00	0.18	.00
Right hand grip (pounds)	−0.12	.01	−0.11	.00	−0.03	.50	−0.03	.12
Left hand grip (pounds)	−0.12	.01	−0.11	.00	−0.02	.71	−0.03	.16
Average hand grip (pounds)	−0.12	−.01	−0.11	.00	−0.03	.59	−0.03	.13
Protein bound iodine (μg/100 mL)	0.03	.61	0.06	.00	−0.00	.93	0.03	.17

significantly correlated with bone age or Tanner stage of male genital development or pubic hair development in boys or with Tanner stage of breast development or pubic hair development in girls. Within sex-race groups, heart rate was not significantly correlated with family income, parents' education level, or size of the place of residence except for a small correlation with the mother's education in boys (blacks, Kendall's $\tau = -0.07$, $P = .05$; whites, Kendall's $\tau = 0.05$, $P = .01$).

Serum protein bound iodine concentration was not significantly correlated with heart rate except in white boys aged 15 to 17 years. Regular smoking was associated with lower heart rates in each sex-race group independent of age. Racial differences in smoking were small and did not explain racial differences in heart rate.

The sex-specific differences between blacks and whites in heart rate were essentially unchanged by adjustment for age (months), height, subscapular skinfold thickness, body temperature, and systolic blood pressure. The mean differences were boys, unadjusted 8.4 beats per minute, adjusted 8.4; girls, unadjusted 9.8 beats per minute, adjusted 9.7. However, these adjusted means must be regarded with caution because the regression lines for blacks and whites are not strictly parallel as shown by an F test comparing models with terms for interaction of race with other variables to models without such terms for boys and for girls.

Another way to assess the independent effect of race on heart rate was to enter race along with multiple other variables in a stepwise linear multiple regression analysis done for each sex. This analysis

TABLE 3. STEPWISE REGRESSION ANALYSIS OF HEART RATE ON OTHER VARIABLES IN YOUTHS AGED 12 TO 17 YEARS BY SEX AND RACE

Variable*	Coefficient**	Standard Error	R^2
White boys			
Age (months)	−0.165	0.017	0.026
Systolic blood pressure	0.196	0.023	0.057
Body temperature	3.050	0.472	0.072
All 8 variables			0.086
Black boys			
Age (months)	−0.195	0.044	0.063
Body temperature	5.862	1.295	0.150
Subscapular skinfold	0.474	0.202	0.177
Systolic blood pressure	0.147	0.067	0.191
All 8 variables			0.200
White girls			
Age (months)	−0.013	0.018	0.002
Systolic blood pressure	0.239	0.028	0.044
Body temperature	4.096	0.585	0.065
Smoking	−5.644	1.109	0.075
All 10 variables			0.090
Black girls			
Age (months)	−0.068	0.034	0.008
Body temperature	8.150	1.219	0.100
All 10 variables			0.128

* Variables that added at least 0.9 percent to the R^2 and whose regression coefficients were statistically significant ($P < .05$). Age was forced to enter the model first regardless of significance.
** Regression coefficient with all listed variables in the model

showed that race was predictive of resting heart rate in boys independent of age, height, subscapular skinfold thickness, systolic blood pressure, serum cholesterol, hematocrit, mother's educational level, peak exercise heart rate, and heart rate change with exercise. In girls, race was predictive of resting heart rate independent of age, subscapular skinfold thickness, systolic blood pressure, serum uric acid, serum cholesterol, hematocrit, peak exercise heart rate, and heart rate change with exercise.

In addition, regression models for heart rate were fitted separately for each sex-race group. The stepwise procedure could select among the following variables: boys, age (months), height, subscapular skinfold thickness, hematocrit, systolic blood pressure, mother's education level, body temperature; girls, age, height, subscapular skinfold thickness, systolic blood pressure, diastolic blood pressure, serum cholesterol, serum uric acid, body temperature, cigarette smoking (0 = never smoked, 0.5 = formerly smoked, 1 = currently smoke). Table 3 shows the statistically significant variables that explained at least 0.9 percent of the variance in heart rate for each race-sex group. More of the variance in heart rate was explained by other variables for boys than for girls.

Models were also fitted with terms for interactions of age with systolic blood pressure and subscapular skinfold thickness. An age–blood pressure interaction was significant only for white boys (b = 0.0008). Similarly, an age-skinfold interaction was significant only for white boys (b = 0.0009). Models were fitted for age subgroups 12 to 15 years and 16 to 17 years. In the group 12 to 15 years of age, the variables selected by stepwise regression were the same as those shown on Table 3 except for hematocrit (b = 0.659) replacing smoking in white girls, and smoking (b = 0.638) and hematocrit (b = 0.521) being added for black girls. In the group 16 to 17 years of age, the variables selected were as in Table 3 with the following exceptions: subscapular skinfold (b = 0.390) was added for white boys; parental education (b = 0.463) replaced skinfold and systolic blood pressure in black boys; diastolic blood pressure (b = 0.355) replaced systolic and serum cholesterol (b = 0.058) was added for white girls; cholesterol (b = 0.143), height (b = 0.528), uric acid (b = 0.237), and diastolic blood pressure (b = 0.207) were added for black girls.

Tracking of heart rate was examined for each sex race group in the cohort examined in Cycles II and III of the Health Examination Survey. The Kendall rank correlations were as follows: white boys 0.23, P = .001, n = 922; black boys 0.30, P = .000, n = 124; white girls 0.21, P = .001, n = 809; black girls, 0.21, P = .001, n = 121. Correlation coefficients did not vary consistently among quartiles of follow-up duration in any sex-race group. Cycle II heart rates were significantly correlated with Cycle III systolic and diastolic blood pressures in whites with coefficients as follows: white boys 0.09, 0.11; black boys 0.15, 0.12; white girls 0.13, 0.13; black girls −0.06, −0.04.

Stepwise linear multiple regression analysis yielded models for predicting resting heart rate at Cycle III from variables measured in Cycle II and the change in variables between examination for each sex-race group. Variables were eligible to enter the model only if they were significantly correlated with Cycle III heart rate in bivariate correlation analysis. The length of the follow-up period was restricted to 28 to 53 months and the length of follow-up forced to enter each model before other variables to control for possible confounding. Variables that explained at least 0.9 percent of the variance in Cycle III heart rate were (R^2 after entry): white boys, Cycle II pulse rate (0.10), age (0.11), systolic blood pressure (0.12), change in systolic blood pressure (0.13); black boys, Cycle II pulse rate (0.12), change in subscapular skinfold thickness (0.16), age (0.18), systolic blood pressure (0.20), change in diastolic blood pressure (0.21); white girls, Cycle II pulse rate (0.11), age (0.13), systolic blood pressure (0.14), change in systolic blood pressure (0.15); black girls, Cycle II pulse rate (0.07), diastolic blood pressure (0.10). Cycle II pulse rate was not an independent predictor of Cycle III blood pressure after controlling Cycle II blood pressure and other variables (National Center for Health Statistics, unpublished data).

In other stepwise regression models with systolic blood pressure as the dependent variable, heart rate was confirmed to be independently associated with systolic blood pressure after controlling multiple other variables as in previous models in white and black boys. Regression coefficients of heart rate were as follows: white boys unadjusted 0.084 SE 0.018, adjusted 0.091 SE 0.015; black boys unadjusted 0.066 SE 0.057, adjusted 0.118 SE 0.051; white girls unadjusted 0.142 SE 0.014, adjusted 0.109 SE 0.013; black girls unadjusted 0.028 SE 0.037, adjusted −0.014 SE 0.035. In other words, a 10 beat per minute increase in heart rate, on average, would be associated with about 1 mmHg rise in systolic blood pressure in white boys, white girls, and black boys given that other variables were held constant.

DISCUSSION

The present data from a nationwide survey confirms a report from a local population that black adolescents have lower heart rates than white adolescents.[6] This difference could not be explained statistically by any of the variables measured in the Health Examination Survey. Blood pressure was most strongly related to heart rate in white girls. Tracking of resting heart rate over a 23- to 53-month period was similar in blacks and whites.

As might be expected, the Health Examination Survey standing-resting heart rates were higher than reported supine or seated heart rates for black and white adolescents.[6,14,21,22,23] The effect of posture on heart rate is well documented.[24] Anticipation of the upcoming exercise may also have elevated heart rates.[24] The present data show that the racial difference persists regardless of body posture. Posture may also be a factor in the failure of heart rate to decrease with age in women. In a study of black adolescents, supine but not seated pulse rates declined consistently with age in women.[22] The significance of this finding is unclear. The higher double product in whites compared with blacks is consistent with published reports.[6] Similar to reports of others, there was a greater correlation of blood pressure with pulse in whites compared with blacks in the HES.[6] The negative relationship of smoking to resting heart rates in adolescents has also been reported by others.[6] This contrasts with the positive relationship of smoking to heart rate reported for adults.[5]

Limitations of the present study include possible bias in the tracking analysis due to the different methods used at the two examinations, standing heart rate (Cycle III) being systematically higher than supine heart rate (Cycle II). A systematic change would not affect the rank order correlation results. Inter- and intra-observer reliability of pulse rate measurements were reported to be about $r = 0.8$ for observations 5 to 10 minutes apart.[22] In cross-sectional analyses, the correlation coefficients of exercise heart rate variables with baseline resting heart rate are subject to bias

TABLE 4. SOME VARIABLES ASSOCIATED WITH RESTING HEART RATE

Environment
Diet
Exercise
Stress*
Organism
Age, sex, race
Lean body mass*
Body fat mass*†
Posture
Oxygen carrying capacity of blood†
Cardiac, pulmonary, renal function*
Cardiovascular fitness
Emotions
Body temperature
Tissue
Thyroid hormone
Extracellular ion concentrations
Blood volume
Right atrial pressure
Arterial pressure*
Sympathetic nervous tone*†
Parasympathetic nervous tone
Epinephrine
Drugs
Sino atrial node cells
Level of maximal diastolic repolarization
Level of threshold potential
Rate of diastolic depolarization

* Black-white difference in adults
† Black-white difference in children

arising from measurement error and regression to the mean, which might tend to induce the high negative correlations observed between change in heart rate and resting heart rate (Table 2). For this reason, these variables were not included in the final regression analyses. Thus, fitness could not be assessed as a predictor of resting heart rate.

Variables related to resting heart rate are shown in Table 4.[24] Variables thought to differ between blacks and whites are indicated.[25] Data from another study suggest that the lower resting heart rates in blacks between the ages of 6 and 34 years arise from a more rapid decline of heart rate with age in blacks compared with whites aged 15 months to 6 years.[26] Black newborns and infants up to 15 months of age had higher resting heart rates than white infants.[27] Similarly, the disappearance of the racial difference after age 34 may occur because of a rise of mean resting heart rate with age in blacks compared with little or no change in white men and a decrease in white women aged 18 to 44 years.[5] The reasons for such differences related to development or aging are unknown. The lower serum dopamine β-hydroxylase and renin values reported in blacks compared with whites may indicate lower sympathetic nervous tone in blacks.[6,28,29] It has been hypothesized that a relatively expanded blood volume in young blacks compared with whites, with contraction of blood volume at older ages in blacks due to high blood pressures, may explain these patterns.[26,27,30] Differences in renal handling of sodium in blacks compared with whites were postulated to explain possible blood volume differences. However, little data on blood volume throughout this age span exist to support this theory. The hypothesis is not consistent with the finding of no racial pulse difference over the age of 35 years even after controlling for blood pressure.[5]

Further, American Indian adults and children had lower resting heart rates than blacks or whites, but Indians had no higher prevalence of hypertension as adults than whites and much lower prevalence than blacks.[4,31] Oriental and Hispanic school children had heart rates similar to whites, all greater than those of blacks.[32] Further research is needed to explain the physiological differences in heart rate between races and sexes and to determine their relationship to cardiovascular mortality and all-cause mortality, hypertension, and other cardiovascular morbidity.

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