Sex and Race Differences in Cardiovascular Disease Risk Factor Changes in Schoolchildren, 1975–1990: The Princeton School Study

John A. Morrison, PhD, Frederick W. James, MD, Dennis L. Sprecher, MD, Philip R. Khoury, MS, and Stephen R. Daniels, MD, PhD

ABSTRACT

Objectives. This study was done to assess changes in obesity and risk factors for cardiovascular disease (CVD) in Black and White children from 1975 through 1990.

Methods. A cross-sectional study of body composition and CVD risk factors conducted in a school district as part of the Lipid Research Clinics (LRC) Program Prevalence Study (1973–1975) was compared with a later study (1989–1990) conducted in the same school district, which remained demographically stable. The studies included 1456 third- and fifth-grade students and 300 LRC subjects within the same age ranges.

Results. Students in the 1989–1990 study had a significantly higher mean body mass index (BMI), total blood cholesterol concentration, and systolic and diastolic blood pressures and marginally higher resting heart rates than those in the earlier study. The prevalence of obesity increased from 12.5% to 25.3%, and of hypercholesterolemia from 8.0% to 14.8%. Black females had the largest increase in BMI and resting heart rate and the highest prevalence of elevated total cholesterol in the 1989–1990 study.

Conclusions. The results of this study suggest a secular trend toward increased obesity in children and portend the potential development of a public health problem that could reverse the recent decline in morbidity from CVD. (*Am J Public Health.* 1999;89:1708–1714)

The decline in cardiovascular disease (CVD) mortality in the United States since the 1950s has been well documented.[1] Several studies of adult populations have shown reductions in risk factors such as high cholesterol levels, blood pressure (BP), and smoking over the period of decline in CVD mortality, suggesting that much of the decrease in CVD mortality can be explained by improvement in risk factor status.[2,3] Because the genesis of atherosclerosis occurs in childhood, it is of interest to determine whether and to what degree CVD risk profiles have changed in children over the period of decline in CVD mortality. Webber et al. reported an increase in ponderal index over 6 cross-sectional surveys conducted from 1973–1974 to 1987–1988 in Bogalusa, Louisiana, but no trends in blood lipid levels.[4]

The purpose of the present study was to evaluate changes in CVD risk factors in schoolchildren in the Princeton (Ohio) School District from 1973–1975 to 1989–1990 and to assess whether there were sex or race differences in the observed trends. The Princeton School District is a geographically well defined suburban school district in southwest Ohio, with a broad representation by race and socioeconomic status. Since the original National Heart, Lung, and Blood Institute (NHLBI) Lipid Research Clinics (LRC) Princeton cohort (1973–1975)[5–7] attended the same schools and lived in the same communities as did the students tested in 1989–1990, the latter students provide a useful comparison group for the study of temporal changes in CVD risk factors.

Methods

The Princeton City School District includes 6 independent, incorporated communities plus unincorporated areas of Hamilton and Butler Counties in Ohio. It is located approximately 15 miles north of the Cincinnati Children's Hospital Medical Center. In 1973 the student population was 70% White and 29% Black, while in 1990 it was 62% White and 37% Black. Census data reveal that the median household incomes in the Princeton School District were comparable to those in the metropolitan Cincinnati area in 1970 and 1990, indicating that the district did not change sociodemographically during the study period.

From 1973 through 1975, Princeton students participated in the LRC Program Prevalence Study.[5–7] After a first visit in which 84% of all students participated, a 15% random sample of participants was recruited for further study at a second visit, at which a fasting lipid profile was recorded, and resting heart rate (HR), blood pressure (BP), height, and weight were measured, and a 24-hour diet recall was obtained. Students in the random sample of the LRC visit-2 population whose ages fell between that of the youngest and oldest students in the 1989–1990 sample (see below) were selected for this comparison.

In 1989 and 1990, a new study was undertaken in the Princeton City School District, targeting students in grades 3 and 5. Students had their height and weight, resting HR, BP, and plasma lipid profiles (total and high-density lipoprotein cholesterol [HDL-C] and triglycerides) measured. In addition, a 3-day

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dietary record was obtained for a sample of third- and fifth-grade students. Overall, 80% of the children had BPs measured and 63% had lipid profiles measured. As a means of determining whether the participating students differed from nonparticipating students with respect to body mass, data on height and weight were obtained for all students as part of the schools' physical-fitness assessment, with the same equipment and procedures used to obtain these data for both groups. These comparisons revealed no significant differences between participants and nonparticipants. Both studies were approved by the appropriate institutional review board, with documented informed consent obtained from the parent or guardian before participation of subjects.

Measurement Methods

Similar methods were used in both studies: students were tested by school and by grade and class within school, with the testing done at the school and beginning about 10 minutes after the start of the school day. Height and weight measurements were taken with students' shoes and outdoor clothing removed. In the LRC study, one measurement of height and weight was made according to a standard procedure as previously described.[8] In the second study, 2 measurements of height and weight were made according to a standard protocol,[9] and a third measurement was made if the first 2 differed by more than 0.5 cm (height) or 0.3 kg (weight). In calculations and analyses, the mean of the recorded measurements was used. For each cohort, the body mass index (BMI) (weight in kilograms divided by height in meters squared) was used as a measure of obesity.

In the LRC study, 2 BP readings were recorded with a standard sphygmomanometer at the onset of the first and fifth Korotkoff phases, and a 15-second measurement of HR was recorded between these 2 readings, as previously described.[10] In 1989–1990, 3 readings of BP were made at the onset of the first, fourth, and fifth Korotkoff phases, following the NHLBI Growth and Health Study protocol,[9] and a 30-second measurement of HR was recorded between the first and second readings. The mean of the second and third readings was used in analyses of BP values. All comparisons of diastolic BP in the 2 cohorts were made with the onset of the fifth Korotkoff phase.

In both studies, blood for complete lipid profiles was drawn into Vacutainer tubes (Becton Dickinson, Inc, Mountain View, Calif) containing ethylenediaminetetraacetic acid, and lipid profile measurements were made in the same laboratory, which followed the standards of the Centers for Disease Control and Prevention (CDC) and NHLBI.[11] In each study, students were told in the recruitment letter to abstain from all food and drink, except water, for 12 hours before blood sampling, and this message was repeated 1 day before the sampling. Compliance with the fasting requirement was ascertained by interview. In the LRC study (1973–1975), a 24-hour diet recall was used to evaluate nutrient intakes.[12] In the current study, a 3-day diet record was used because it gives a measure of interdiurnal variability.[13]

Statistical Analyses

Database management and statistical analyses were done with SAS software.[14] The distributions of variables investigated in our study were examined for normality, and variance-stabilizing transformations were applied when appropriate. Mean values and standard errors (SEs) for age are presented for the 1973–1975 group and the 1989–1990 group. Mean values for all other variables reflect adjustment for differences in age between the 2 groups. Means are presented for the entire group and by sex–race groups in each study. Adjusted means and significance levels were calculated with the LSMEANS option in the GLM procedure.

Standard cutpoints used in clinical practice were employed to determine normal and high levels of anthropometric, lipid, and BP variables: For BP, the sex-age-height–specific 95th percentiles were determined for each child from nomograms compiled by Rosner et al.[15] For BMI, the race-sex-age–specific 85th percentiles were selected from tables of combined National Health and Nutrition Education Survey (NHANES) I and NHANES II data compiled by Frisancho.[16] For total cholesterol the cutpoint was set at 200 mg/dL, as recommended by the National Cholesterol Education Program pediatric guidelines.[17] The proportions of subjects in each group whose values fell above these cutpoints were then compared in the 2 cohorts via χ^2 analysis. To investigate whether changes from the 1973–1975 cohort to the 1989–1990 cohort occurred across the entire distribution or whether the changes appeared in only a particular part of the distribution of subjects, we plotted cumulative percentages for risk factors for the 2 cohorts, to allow visual observation of overlaps and differences.

Results

Age and Body Mass

The mean age of the students in the original Princeton LRC study was 0.4 years greater (10.2 ± 0.06 vs 9.8 ± 0.03 years, $P<.001$) than that of students in the 1989–1990 study. The range of ages was similar for the 2 cohorts (7.2–12.8 years in 1973–1975 and 7.4–12.8 years in 1989–1990). The sex ratios of the study samples in 1973–1975 and 1989–1990 were similar (50% and 49% male, respectively) and the race ratios were similar (72% and 69% White, respectively).

Across all participants, students in the 1989–1990 study were taller ($P<.001$), were heavier ($P<.001$), and had greater BMI values ($P<.001$) than those in the 1973–1975 LRC study; this was true whether raw data or data adjusted for age were used. Table 1 presents the age-adjusted means and SEs for all study variables. Differences in weight and BMI for each sex–race group in the 2 studies were also significant, except for Black males, for whom the difference in BMI was marginally significant (Table 1). Cumulative frequency distributions of BMI for the total cohorts and separate sex–race groups in the 1973–1975 and 1989–1990 studies revealed that differences in BMI between the cohorts were minimal at the lower end of the BMI distributions, began at approximately the 40th percentile, and increased with increasing BMI, demonstrating that equivalent percentiles were indicative of a higher BMI in the 1989–1990 cohort than in the 1973–1975 cohort (Figure 1). These distributions also showed that the shift in BMI had an impact on all but the lower end of the distributions, but that the biggest shift in BMI occurred above the 75th percentile. In the 1973–1975 cohort, the percentage of children with a BMI above the 85th percentile of the combined NHANES I and II survey samples was 12.4%, compared with 25.3% in the 1989–1990 cohort ($P<.001$). The prevalence of obesity in the 1989–1990 cohort was significantly greater in every sex–race group except Black males than it was in the 1973–1975 cohort (increase for Black males: 24.3% to 32.6%, P = not significant [NS]). Black females had the greatest increase in BMI.

Plasma Lipids and Lipoproteins

Plasma lipid profiles in the 1973–1975 and 1989–1990 study cohorts are summarized for all students and by sex–race groups in Table 1. An examination of total cholesterol levels by sex–race group revealed that in both studies, Black males and females had higher total cholesterol levels than did White males and females. Sex differences within each race group were, however, minimal and nonsignificant. Mean total cholesterol was higher in the 1989–1990 than in the 1973–1975 study cohorts for all students taken together (170.5 vs 164.6 mg/dL, $P<.01$) (Table 1), but not for each individual subgroup. Differences in mean total cholesterol were

TABLE 1—Characteristics of Princeton (Ohio) Students, 1973–1975 and 1989–1990

	Overall		White Males		Black Males		White Females		Black Females	
	1973–1975	1989–1990	1973–1975	1989–1990	1973–1975	1989–1990	1973–1975	1989–1990	1973–1975	1989–1990
Anthropometry	n = 299	n = 1456	n = 108	n = 492	n = 37	n = 224	n = 109	n = 515	n = 45	n = 225
Height, cm	137.8 ± 0.39	139.5 ± 0.18***	137.6 ± 0.61	139.2 ± 0.28*	137.5 ± 1.15	142.2 ± 0.47***	137.2 ± 0.66	138.1 ± 0.30	139.4 ± 1.00	140.8 ± 0.44
Weight, kg	32.4 ± 0.53	36.2 ± 0.24***	32.8 ± 0.77	34.5 ± 0.35**	33.5 ± 1.91	38.7 ± 0.77**	31.4 ± 0.85	35.3 ± 0.39***	32.7 ± 1.38	38.4 ± 0.62***
BMI	16.9 ± 0.21	18.3 ± 0.10***	17.1 ± 0.14	17.9 ± 0.32*	17.5 ± 0.74	18.9 ± 0.30†	16.6 ± 0.34	18.2 ± 0.16***	16.8 ± 0.55	19.0 ± 0.24***
Lipids (mg/dL)	n = 299	n = 1017	n = 108	n = 357	n = 37	n = 146	n = 110	n = 359	n = 44	n = 155
Total cholesterol	164.6 ± 1.62	170.5 ± 0.87**	161.9 ± 2.83	166.4 ± 1.54	173.1 ± 4.69	170.5 ± 2.36	161.6 ± 2.15	172.0 ± 1.37***	169.4 ± 4.09	176.9 ± 2.18
Triglycerides	62.1 ± 1.71	66.4 ± 0.92*	57.5 ± 2.72	64.5 ± 1.48*	52.2 ± 3.16	52.8 ± 1.59	68.9 ± 3.16	75.4 ± 1.72†	61.6 ± 3.73	63.8 ± 1.98
HDL-C	55.7 ± 0.68	56.1 ± 0.36	56.1 ± 1.07	55.5 ± 0.58	63.2 ± 2.08	60.9 ± 1.04	52.0 ± 0.99	53.5 ± 0.54	58.3 ± 1.91	57.9 ± 1.00
LDL-C	99.0 ± 1.48	101.1 ± 0.79	96.2 ± 2.64	97.7 ± 1.43	102.3 ± 4.37	99.0 ± 2.2	98.6 ± 2.26	103.4 ± 1.23†	102.7 ± 3.53	106.2 ± 1.85
Blood pressure	n = 300	n = 1286	n = 108	n = 446	n = 37	n = 184	n = 110	n = 470	n = 45	n = 186
Systolic, mm Hg	98.8 ± 0.53	101.7 ± 0.25***	99.1 ± 0.83	101.5 ± 0.40**	98.3 ± 1.60	103.2 ± 0.72**	98.3 ± 0.87	101.4 ± 0.41***	99.1 ± 1.48	101.6 ± 0.71
Diastolic, mm Hg	57.7 ± 0.62	59.6 ± 0.30**	58.8 ± 1.02	59.1 ± 0.51	58.6 ± 1.92	61.1 ± 0.88	56.9 ± 0.99	59.7 ± 0.48**	56.8 ± 1.59	59.9 ± 0.78
Heart rate, bpm	79.0 ± 1.40	81.7 ± 0.67†	78.0 ± 1.11	80.2 ± 0.53†	76.4 ± 1.77	78.4 ± 0.79	81.6 ± 3.58	84.4 ± 1.71	76.7 ± 1.70	81.6 ± 0.82**
Diet	n = 297	n = 953	n = 108	n = 341	n = 34	n = 105	n = 110	n = 380	n = 45	n = 127
Total calories	1992 ± 37.5	1933 ± 21.0	2270 ± 63.0	2051 ± 35.2**	1565 ± 145.3	2273 ± 86.2***	2041 ± 49.0	1795 ± 26.2***	1585 ± 79.0	1742 ± 47.0†
% fat	37.6 ± 0.36	35.4 ± 0.20***	36.6 ± 7.57	35.4 ± 0.32†	40.2 ± 1.26	37.0 ± 0.75*	36.6 ± 0.54	34.6 ± 0.28***	40.0 ± 1.11	36.5 ± 0.66**
% saturated fat	15.0 ± 0.17	13.6 ± 0.10***	15.1 ± 0.29	13.8 ± 0.16**	15.4 ± 0.56	14.0 ± 0.33*	14.6 ± 0.26	13.4 ± 0.14***	15.9 ± 0.47	13.6 ± 0.28***
P/S ratio	0.40 ± 0.01	0.47 ± 0.01***	0.38 ± 0.18	0.45 ± 0.01***	0.48 ± 0.04	0.48 ± 0.21	0.41 ± 0.02	0.47 ± 0.01**	0.39 ± 0.29	0.50 ± 0.17***

Note. BMI = body mass index; HDL-C = high-density lipoprotein cholesterol; LDL-C = low-density lipoprotein cholesterol; bpm = beats per minute; P/S ratio = polyunsaturated-to-saturated fat ratio.

**P* < .05; ***P* < .01; ****P* < .001; †.05 < *P* < .10.

highly significant for White females ($P<.001$) and marginally significant for Black females ($P=.11$) but not for White males, despite an increase of 4.5 mg/dL in mean total cholesterol, or for Black males, who had no increase in this variable.

The cumulative frequency distribution of total cholesterol for both the 1973–1975 and 1989–1990 total cohorts and individual sex–race groups within the 2 cohorts revealed similar shifts in Black and White females and White males, although only that in White females achieved significance (Figure 2). The figures also showed that the differences in total cholesterol were small at and below the 25th percentile and increased as the percentile level increased, in concordance with the shifts in BMI. For Black males, total cholesterol curves in the 1989–1990 study were lower than in the 1973–1975 study. The prevalence of elevated total cholesterol (>200 mg/dL) increased from 8.0% in the 1973–1975 cohort to 14.8% overall ($P<.01$) in the 1989–1990 cohort. Black females had the largest increase (6.8% to 21.3%).

In the 1989–1990 study, as in the 1973–1975 study, White students had higher triglyceride levels than did Black students, and females had higher triglyceride levels than did males (Table 1). Across all groups, the increase in triglyceride levels from the 1973–1975 to the 1989–1990 study was 4.3 mg/dL ($P < .05$). Differences in triglycerides between sex–race groups in the 2 study cohorts were not significant, except for White males ($P<.05$). In 1989–1990, as in 1973–1975, Black students had higher HDL-C values than did White students. The overall mean HDL-C level was not significantly different in the 1973–1975 cohort than in the 1989–1990 cohort (55.7 vs 56.1 mg/dL, $P=$ NS), nor were the mean HDL-C levels different for the individual sex–race groups. Mean low-density lipoprotein cholesterol (LDL-C) levels in the overall cohorts in the 2 studies were not significantly different, nor were LDL-C levels in the individual sex–race groups significantly different between the 2 cohorts, except for White females, for whom the LDL-C level was marginally ($P=.06$) higher in 1989–1990 than in 1973–1975 (Table 1).

Blood Pressure and Heart Rate

Among all students investigated, participants in the 1989–1990 study had significantly higher systolic (101.7 vs 98.8 mm Hg, $P<.001$) and diastolic (59.6 vs 57.7 mm Hg, $P<.01$) BP levels than did Princeton students in the 1973–1975 study (Table 1). Systolic BP levels were higher in each sex–race subgroup in the 1989–1990 cohort than in the 1973–

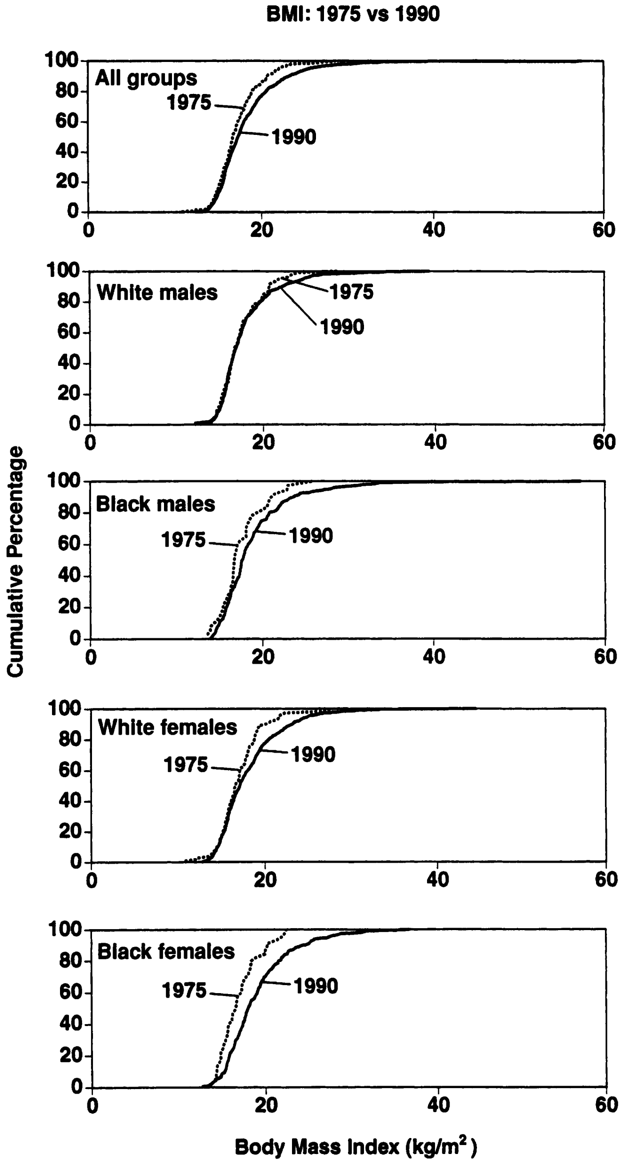

FIGURE 1—Comparison of body mass index (BMI) distributions for 2 cohorts of students in the Princeton School District overall and by sex–race group. Points represent the percentage at or below a given BMI.

1975 cohort, but differences were significant only for Black males (103.2 vs 98.3 mm Hg, $P<.01$) and White males (101.5 vs 99.1 mm Hg, $P<.01$). Mean diastolic BP across all students or in any subgroup was not significantly higher in one study than in the other. Mean HR was 2.7 beats per minute (bpm) higher in the 1989–1990 cohort ($P=.08$). The within-subgroup differences in mean HR ranged from 2.0 bpm higher in Black males to 2.2 and 2.8 bpm higher in White males and females, respectively, and 4.9 bpm higher in Black females in the 1989–1990 study than in the corresponding groups in the 1973–1975 study. Only in Black females was the difference statistically significant ($P=.007$).

Cumulative frequency distributions of systolic BP showed a modest shift to the right across the range of percentiles, with students in the 1989–1990 study having higher BPs than students in the 1973–1975 cohort (Figure 3). The prevalence of elevated systolic BP did not change significantly from the 1973–1975 to the 1989–1990 study (4.3% vs 2.8%, $P=$ NS). The prevalence of elevated diastolic BP, however, decreased significantly from the earlier to the later study (2.7% vs 0.6%, $P<.01$). Although each sex–race group showed a decline in the prevalence of elevated diastolic BP, only White males (2.8% to 0.2%, $P<.001$) and Black females (4.4% to 0.0%, $P<.05$) showed significant decreases in the prevalence of increased diastolic BP.

Nutrition

Students reported consuming slightly fewer calories in 1989–1990 (1933 vs 1992 cal/day), but this difference was not significant. However, differences in calorie intake in the 2 study cohorts differed markedly by race. White males and females reported consuming significantly fewer calories, whereas Black males and females reported consuming more. Students overall and in each sex–race group in the 1989–1990 cohort reported consuming a lower percentage of calories from fat, a lower percentage of calories from saturated fat, and a higher ratio of polyunsaturated (P) to saturated (S) fat than those in the 1973–1975 cohort, except for the P/S ratio in Black males.

Discussion

The results of this study of changes in body mass and CVD risk factors in third- and fifth-grade students over a 15-year period indicate increases in BMI and in some risk factors. The increase in BMI was seen across all students collectively and in each sex–race group from the 1973–1975 study to the 1989–1990 study, although the increase was only marginally significant in Black males. The change was even more striking when the upper range of BMI was examined. In the 1989–1990 study, the proportion of students with a BMI exceeding the 85th percentile, on the basis of values in NHANES I and II, was more than twice as great as that in the 1973–1975 study (25.3% vs 12.4%). This finding is consistent with changes reported by others.[4,18]

Although an increase in BMI from the 1973–1975 study to the 1989–1990 study was seen in each sex–race group, the BMI changes differed across sex–race groups, partly because of small sample sizes in the subgroups. The increase was smallest in White males (4.7%) and greatest in Black females (13.1%), with intermediate increases in Black males (8.0%) and White females (9.6%). Gidding et al. also found sex–race group differences in changes in weight and body mass over an 8-year period in the Bogalusa study, but they reported that only the changes in Black females were significant.[19] One potential explanation for the different results in their study and ours is that the Bogalusa analysis covered the period from 1973 to 1984. National survey data suggest that the greatest change in obesity in the United States occurred between NHANES II (1976–1980) and NHANES III (1988–1991).[18,20] Thus, the study of the second Bogalusa cohort may have begun before the beginning of a national trend toward increased childhood obesity. A second

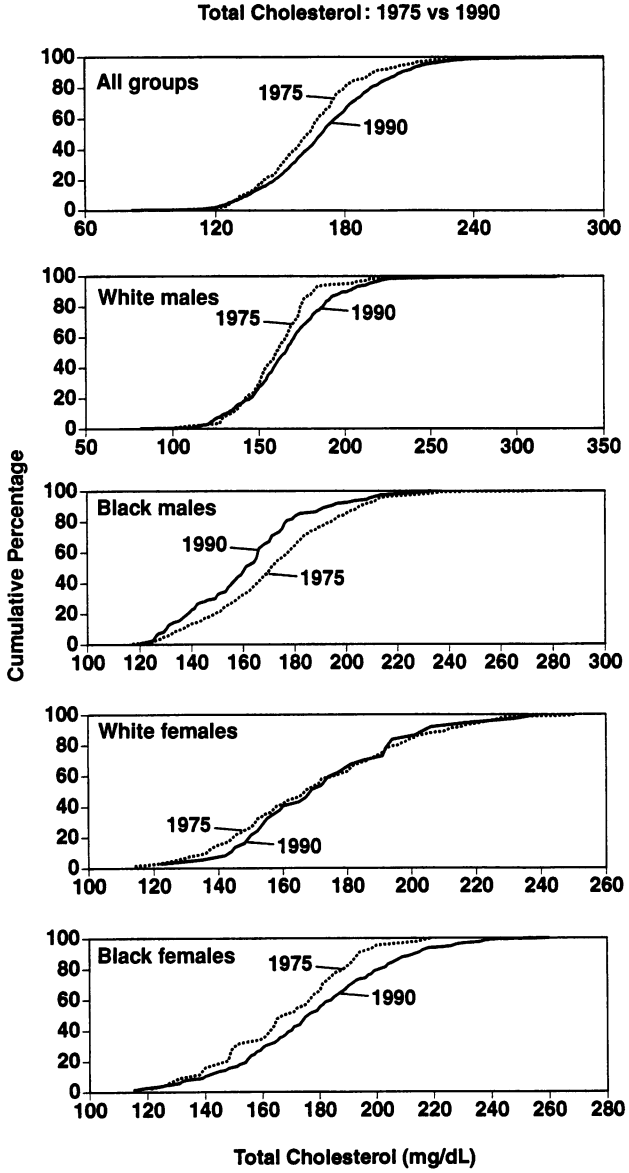

FIGURE 2—Comparison of total cholesterol distributions for 2 cohorts of students in the Princeton City School District overall and by sex–race group. Points represent the percentage at or below a given level of total plasma cholesterol.

possible explanation for the different results in our study and that of Giddings et al. is the difference in geographic area in the 2 studies. Geographic differences in CVD mortality and risk factor status have been described for adults[1] and may also exist for school-aged children.

In the present study, increases in weight and body mass were greater in the top deciles than in the lower deciles. There was no change in percentile levels at or below the 25th percentile, but the 75th percentile for BMI increased from 18.5 in the 1973–1975 study to 19.7 in the 1989–1990 study; this finding is consistent with that of Gortmaker et al.,[21] who reported an increased skewness of BMI distribution from 1963 through 1965 to 1976 through 1980. These results suggest that the observed increase in body size is not a general phenomenon but is restricted to a subgroup of the childhood population at the upper end of the distribution of body mass who have become even more overweight in recent years. This trend may result in an increased frequency of the sequelae of obesity, such as type II diabetes. We have observed such an increase in this diagnosis in adolescents in the greater Cincinnati area over the past 10 years.[22]

The mean total cholesterol and triglyceride levels of Princeton schoolchildren were significantly higher in 1989–1990 than in 1973–1975, a trend that runs counter to those reported for adults.[23] It is unlikely that the changes in lipid levels observed in our study were due to laboratory differences, because all lipid profiles were measured in the same CDC-NHLBI–standardized laboratory. In 2 cohorts enrolled 11 years apart (1973–1984), Gidding et al. found a significantly greater increase in triglyceride levels in the later cohort over 8 years of follow-up[19] but found no cohort differences in lipid values at baseline. In the present study, the comparisons were made of groups examined in 1973–1975 and 1989–1990, and increases in total cholesterol were observed from the former to the latter period for both White ($P<.001$) and Black ($P=.11$) females, in which groups there were also significant increases in the prevalence of elevated cholesterol.

It is difficult to interpret the dietary data of our study in context. The decrease in total calories in White males and females is not consistent with observed changes in BMI, but the greater increases in BMI in Black males and females, who did have greater reported caloric intakes, are consistent with such changes. Moreover, the dietary findings in our study are consistent with reported decreases in calorie and fat consumption and increases in ponderosity seen in Bogalusa, where there was no change in the method used for collection of dietary data. The changes in the proportion of dietary calories from fat and saturated fat and in P/S fat ratios from the 1973–1975 study to the 1989–1990 study were also most likely real. A comparison of results from the 24-hour diet recall and 3-day record in the 2 studies showed similar results for the proportion of calories from fat and P/S ratios despite differences in absolute quantities of dietary calories (i.e., total calories) and grams of fat in the 2 studies.[24]

As has been noted, overall fat intake in the United States has decreased from 40% of total calories in the 1950s and 1960s to about 33% in recent years.[25] Further, the amount of polyunsaturated fat intake has risen in comparison with that of saturated fat. The decrease in fat intake has resulted, however, in a dramatic increase in carbohydrate consumption, especially that of simple sugar. It has been suggested that these shifts are responsible for the increased body weight observed both nationally in the United States[26] and in the present study. Even though BMI does not profoundly increase total cholesterol concentrations, the 2 are positively associated. Moreover, these data are consistent with the arguments of Connor and Connor and of Katan et al. in the recent clinical debate regarding the benefits of a low-fat, high-carbohydrate diet.[25,26] Both sides agree that the fat content

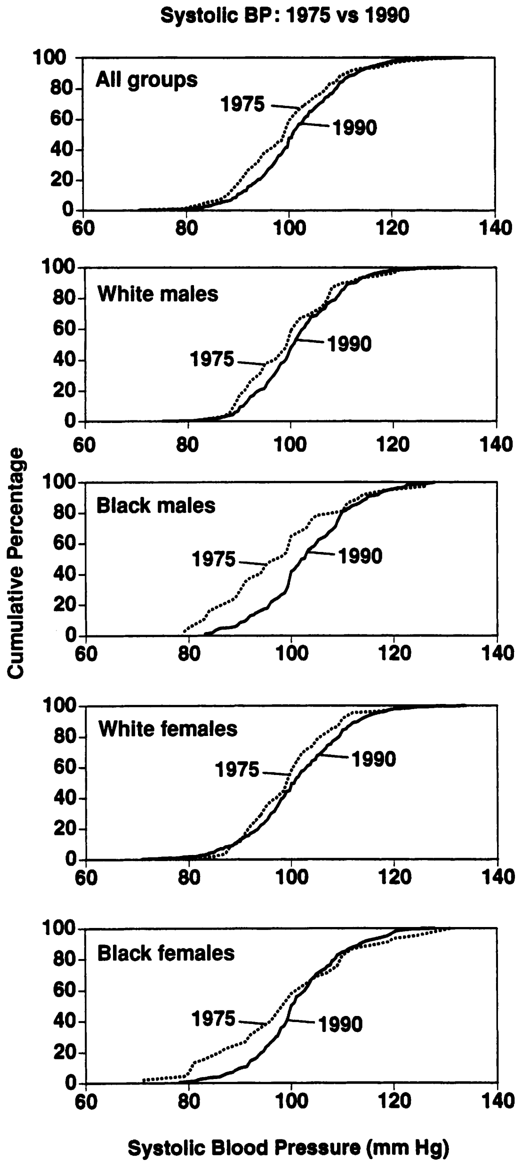

FIGURE 3—Comparison of systolic blood pressure (BP) distributions for 2 cohorts of students in the Princeton School District overall and by sex–race group. Points represent the percentage at or below a given level of systolic BP.

of Americans' diets is being reduced but is being replaced by simple sugars.

The increase in BMI among school-aged subjects in Princeton from 1973–1975 to 1989–1990, in the face of observed changes in total calories and fat (decreased in White students and increased in Black students), suggests that total energy expenditure decreased from the earlier to the later period. Energy expenditure was unfortunately not measured in either period. However, data from other sources indicate that after-school activity has diminished in the United States in recent years. Dietz and Gortmaker reported an increase in television watching that appears to be related to increased obesity.[27] Anderssen et al. reported a secular trend of decreasing physical activity in young adults.[28] It has been suggested that resting HR is a risk factor for CVD and may be a measure of physical fitness. Resting HRs were marginally higher in all sex–race groups in the 1989–1990 than in the 1973–1975 Princeton cohorts and were markedly higher in Black females, the group that also had the greatest change in BMI. This result may indicate that changes in physical activity and fitness played an important role in the changes observed in BMI, HR, and lipids from the first to the second study.

The systolic BP increased to 101.7 mm Hg in the 1989–1990 study cohort from 98.8 mm Hg in the 1973–1975 cohort; the observed changes were slightly greater in Blacks (3.6 mm Hg) than in Whites (2.8 mm Hg) (data not shown). Changes in mean diastolic BP were statistically significant across all students, but not in the sex–race groups. There was a significant decline in the prevalence of elevated diastolic blood pressure in White males and Black females. It is well known that BP is directly associated with body size. Therefore, the increased systolic BP observed in students from 1973–1975 to 1989–1990 is consistent with the observed increases in weight and BMI during this same period. These findings in children appear to differ from the data for adults in NHANES III, which suggest that the distributions of systolic and diastolic BP shifted downward during the 30-year period from 1960 to 1990.[29] The trend toward a decreasing prevalence of elevated diastolic blood pressure observed in the present study may, however, be more consistent with BP trends seen in adults.

The changes in CVD risk factors associated with changes in obesity observed in our study were not uniform for all groups. The increased prevalence of hypercholesterolemia in White and Black females, and the absence of a significant increase in this risk factor in White and Black males, are not fully consistent with the observed increases in BMI, which were marginally significant in Black males and significant in the other study subgroups. Of interest is that Black males exhibited a marginally increased BMI without a concomitant increase in total cholesterol. On the other hand, Black males did exhibit a significant increase in systolic BP, whereas other sex–race groups did not. Black males have been shown to have higher peripheral vascular resistance than other sex–race groups.[30,31] Thus, it is possible that the increase in cardiac output that has been shown to occur with obesity may have a greater impact on BP in Black males than in other sex–race groups. This finding suggests that the effect of increasing obesity may not be uniform in the 4 sex–race groups examined in our study.

The findings of this study suggest a disturbing secular trend toward increased obesity and worsened CVD risk status in children in the United States. These temporal changes may have important implications for understanding potential sex–race differences in the pathophysiology of the sequelae of obesity. Furthermore, the trends toward increased obesity and worsened CVD risk status among children in the United States suggest the development of a public health problem, which could lead to a reversal of the recent decline in cardiovascular morbidity and mortality as these children become adults. □

Contributors

J. A. Morrison was the principal investigator for the study and oversaw the study design, data collection and analyses, and writing of the paper. F. W. James and D. L. Sprecher joined J. A. Morrison in negotiating the project with the school. D. L. Sprecher also performed the lipid profiles and contributed to the interpretation of the lipid results; F. W. James also provided physician coverage at the clinics, helped with the blood pressure training, and contributed to the discussion of indicators of fitness. P. R. Khoury participated in the data analyses. S. R. Daniels participated in the writing of the paper and interpretation of the blood pressure results.

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