Objective: To test for differences in prospective associations between physical activity and obesity among black and white adolescent girls.

Design: Prospective cohort study using data from the National Heart, Lung, and Blood Institute Growth and Health Study.

Setting: Multicenter study at the University of California (Berkeley), Children’s Medical Center at the University of Cincinnati (Cincinnati, Ohio), and Westat, Inc, and Group Health Association (Rockville, Maryland).

Participants: A total of 1148 adolescent girls (538 black and 610 white) who provided valid data on levels of physical activity and obesity at ages 12 and 14 years.

Intervention: Physical activity, assessed as accelerometer counts per day.

Main Outcome Measures: Three measurements of obesity were obtained using the Centers for Disease Control and Prevention definition of obesity (at or above the age-specific 95th percentile of body mass index), the International Obesity Task Force reference body mass index cut points for obesity in children, and the sums of skinfold thickness (with the cohort ≥90th percentile as indicative of obesity).

Results: We found a strong negative dose-response association between quartiles of accelerometer counts per day at age 12 years and obesity at age 14 years (using all 3 measurements of obesity) in white but not black girls (P < .001 for body mass index interaction and P = .06 for sums of skinfold thickness interaction). The odds ratios for obesity (using the cohort ≥90th percentile for sums of skinfold thickness) in adjusted models between the top and the bottom quartiles of accelerometer counts per day were 0.15 (95% CI, 0.04-0.63; P = .03 for trend) in white girls and 0.85 (95% CI, 0.32-2.26; P = .93 for trend) in black girls.

Conclusions: Higher levels of physical activity are prospectively associated with lower levels of obesity in white adolescent girls but not in black adolescent girls. Obesity prevention interventions may need to be adapted to account for the finding that black girls are less sensitive to the effects of physical activity.

interventions promoting activity would have less impact in this high-risk population. Long-term observational data confirm this. After accounting for variations in energy intake, pubertal timing, and smoking status, Kimm et al\textsuperscript{11} found that decreases in levels of habitual physical activity equating to 10 metabolic equivalent tasks per week were associated with increases in body mass index (BMI, calculated as weight in kilograms divided by height in meters squared) that were 0.09 times greater in black girls than in white girls.

Despite this evidence, few researchers have investigated the differential effects of physical activity across races/ethnicities in “free-living” adolescents. In general, conclusions on the role of physical activity in obesity during adolescence have been limited by inconsistent results,\textsuperscript{12} cross-sectional study designs,\textsuperscript{13} and an overreliance on self-report measures and a lack of statistical power.\textsuperscript{14} Studies addressing these limitations using more precise measures of physical activity (eg, accelerometers) and body fat (eg, dual-energy x-ray absorptiometry) have shown a strong inverse association between levels of physical activity and body fat in adolescence.\textsuperscript{15,16} However, these cohorts were predominately of white race, and as such the racial differences in the associations between physical activity and obesity have not been examined.\textsuperscript{11,15,16}

Herein, we sought to add to the literature on the associations between physical activity and obesity in black and white adolescent girls by addressing the following 2 objectives: (1) to document the prospective association between objectively measured physical activity and obesity during a 2-year period in black and white girls and (2) to test for significant differences in the association between levels of physical activity and obesity across black and white.

**METHODS**

**PARTICIPANTS**

We conducted secondary analyses of the National Heart, Lung, and Blood Institute Growth and Health Study (NGHS). A complete description of the NGHS procedures and measures has been previously reported.\textsuperscript{17} Briefly, the NGHS was a multicenter longitudinal study of 1213 black girls and 1166 white girls who were followed up annually from age 9 or 10 years (in 1985) to age 18 or 19 years (in 1995). Race was defined by self-report, and eligible participants had to declare themselves as being of black or white race. Written informed consent from parents and assent from the girls were obtained, and institutional review boards approved the study protocol.

**MEASURES**

Detailed descriptions of the NGHS procedures,\textsuperscript{17} the measurements of obesity (BMI and sums of skinfold thickness [SST]),\textsuperscript{11} and the physical activity measures\textsuperscript{18} have been previously reported. We restricted our analysis to the ages of 12 to 14 years because accelerometer data were not recorded at other waves.

**OVERALL LEVELS OF PHYSICAL ACTIVITY**

Overall levels of daily activity were measured for 3 days using an accelerometer (Caltrac; Hemokinetics, Inc.) at ages 12 to 14 years. The uniaxial accelerometer detects frequency of movement, acceleration, and deceleration in a vertical plane.\textsuperscript{13} The accelerometer has been validated in child\textsuperscript{19} and adult\textsuperscript{20} populations. Participants were instructed to record the time and the count reading on the display window on waking and on going to bed and to keep the accelerometer horizontally in a pouch over the right hip when being worn.

Daily levels of physical activity were calculated by subtracting the waking reading from the bedtime reading. Data from girls who had worn the accelerometer for at least 2 of 3 days were included in the study. The accelerometer score was used to assess total levels of physical activity and represents the mean number of accelerometer counts per day (cpd) during a 2-day or 3-day assessment period. Quartiles of accelerometer cpd at age 12 years were used to look for a dose-response association between objectively measured levels of physical activity and obesity.

**HABITUAL PHYSICAL ACTIVITY**

The Habitual Activity Questionnaire (HAQ) was used to provide information on levels of physical activity that participants engaged in during the past year.\textsuperscript{21} The HAQ is a structured interview that assesses the type and frequency of participation in physical activity during the past year. Participants were asked to list and estimate the frequency of all activities.

The HAQ score was computed by multiplying an estimate of the metabolic equivalent tasks for each recorded activity by the weekly frequency and the proportion of the year during which it was performed. For scoring purposes, the following fractions were assigned: classes and lessons during the year (1 for most of the year, 0.5 for half, and 0.25 for a small part), sports and physical activities during the school year (weekly frequency 0.75 for most of the school year, 0.375 for half, and 0.1875 for a small part), and sports and physical activities during the summer (0.25 for most of the summer, 0.125 for half, and 0.0625 for a small part). The final HAQ score (metabolic equivalent tasks per week) represents the sum of weekly scores for all activities in the previous year. The HAQ has been previously validated against the accelerometer.\textsuperscript{18}

**ADIPOSITY**

All adiposity measures were obtained by centrally trained examiners across sites. Using custom-made stadiometers, height was measured to the nearest 0.1 cm with the girls wearing socks. Weight was measured to the nearest 0.1 kg using calibrated electronic scales (Health o meter; Sunbeam Products, Inc) with the girls wearing a standard-size T-shirt. Body mass index was derived from measurements of height and weight. Percentage body fat was assessed by skinfold thickness, measured using calipers (Holtain Ltd) at the triceps, subscapular, and suprailiac sites, and these measurements were summed.

Three measurements of obesity were used as outcomes in the analysis. First, based on the Centers for Disease Control and Prevention (CDC) guidelines (http://www.cdc.gov/growthcharts/clinical_charts.htm), obese was coded as 1 (at or above the age-specific 95th percentile of BMI) or 0 (below the 95th percentile of BMI). Second, obesity was assessed using the International Obesity Task Force (IOTF) reference body mass index cut points for obesity in children.\textsuperscript{22} Third, because no agreed-on cut points exist for obesity assessed using SST, age-standardized z scores were calculated for black girls and white girls separately using the cohort mean (SD). The SST z scores above the 90th percentile represented obesity. The SST cut points were 3.45 mm (at age 12 years) and 3.18 mm (at age 14 years) for white girls and 40.00 mm (at age 12 years) and 46.28 mm (at age 14 years) for black girls.
proportions were obtained for categorical variables. We used means (SDs) were calculated for continuous variables, and watched and calculated the total television viewing time per week. The NGHS staff determined the length of each program and video channels, and list all videos they watched during the past 7 days. able in their area, note the time spent watching music television they usually watched from a list of all television programs avail-

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Means (SDs) were calculated for continuous variables, and watched and calculated the total television viewing time per week. The NGHS staff determined the length of each program and video channels, and list all videos they watched during the past 7 days. able in their area, note the time spent watching music television they usually watched from a list of all television programs avail-

Table 1. Continuous Measures for Black and White Girls With Objectively Measured Overall Levels of Physical Activity at Age 12 Years and With BMI and SST Measured at Age 14 Years

<table>
<thead>
<tr>
<th>Continuous Measure</th>
<th>All (N = 1148)</th>
<th>Black Girls (n = 538)</th>
<th>White Girls (n = 610)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, mean (SD), y</td>
<td>12.0 (0.6)</td>
<td>12.1 (0.6)</td>
<td>11.9 (0.6)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Physical activity, median (IQR)</td>
<td>277.5 (204.0-354.0)</td>
<td>253.7 (166.9-334.1)</td>
<td>295.9 (229.2-362.5)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Accelerometer counts/d</td>
<td>61.9 (30.4-123.7)</td>
<td>74.2 (42.2-117.7)</td>
<td>86.7 (58.3-127.4)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Height, mean (SD), cm</td>
<td>153.7 (7.8)</td>
<td>155.2 (7.6)</td>
<td>152.5 (7.8)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Weight, mean (SD), kg</td>
<td>48.2 (12.7)</td>
<td>61.1 (13.6)</td>
<td>54.6 (11.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>BMI, median (IQR)</td>
<td>19.2 (17.0-22.3)</td>
<td>19.7 (17.6-23.6)</td>
<td>18.8 (16.5-21.3)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>SST percentage body fat, median (IQR)</td>
<td>20.1 (15.5-26.5)</td>
<td>21.0 (15.5-29.6)</td>
<td>19.7 (15.5-25.1)</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Television viewing, median (IQR), h/wk</td>
<td>33.5 (21.0-48.5)</td>
<td>44.3 (33.0-58.0)</td>
<td>24.5 (15.0-35.1)</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Caloric intake, median (IQR), kcal/d</td>
<td>1908.9 (1535.0-2327.3)</td>
<td>1912.9 (1539.2-2422.8)</td>
<td>1906.8 (1542.4-2273.0)</td>
<td>&lt;.05</td>
</tr>
</tbody>
</table>

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); IQR, interquartile range; METs, metabolic equivalent tasks; SST, sums of skinfold thickness.

- t tests and χ² tests to examine differences between continuous and categorical variables for girls who did and girls who did not provide valid accelerometer data. Spearman rank correlation coefficients were used to describe the associations between accelerometer cpd and self-reports of hours of television viewing per week, daily caloric intake, and habitual physical activity.
- The associations between overall levels of physical activity and changes in obesity were assessed using logistic regression analysis, with indicator contrasts. Effects were summarized using odds ratios (95% CIs) and the Cohen d statistic. We adjusted for a series of possible confounding factors that have been independently associated with obesity in previous investigations. We adjusted for age, height, and height squared (because previous investigators reported a quadratic relationship between height and body fat), social and economic factors (highest level of parental education and total annual household income), distal influences on obesity (daily caloric intake), potential confounds of physical activity (hours of television viewing per week and self-reported total metabolic equivalent tasks per week of physical activity), and self-reported pubertal status at age 12 years and at age 14 years.

Among 2379 girls recruited at age 9 years, 2228 (93.7%) attended at age 12 years, 2159 (90.8%) at age 13 years, and 2056 (86.4%) at age 14 years. Of these girls, 1399 (659 black and 740 white) at age 12 years, 1482 (734 black and 748 white) at age 13 years, and 1473 (724 black and 749 white) at age 14 years returned accelerometers satisfying the validity criteria. Estimates of percentage body fat from height and weight and from SST were available on 1386 girls with valid physical activity measures at age 12 years, on 1461 girls at age 13 years, and on 1452 girls at age 14 years. In total, 1148 adolescent girls (538 black and 610 white) (48.3% of those recruited at age 9 years) provided valid data at ages 12 and 14 years.

The mean (SD) age of the girls at wave 3 was 12.0 (0.6) years. Characteristics of the girls are summarized in Table 1 and in Table 2. At ages 12 and 14 years, girls who attended were more likely to be white and be from a higher social class compared with girls who did not at-

DEMOGRAPHIC INFORMATION

The highest level of parental education (achieved by either parent) and the total annual household income were collected at study entry from parents (or guardians). Based on previous analysis, the highest level of parental education was categorized as high school or less, some college, or a college degree (≥4 years). The total annual household income was categorized as less than $10,000, $10,000 to $19,999, $20,000 to $39,999, or $40,000 or higher. Both the highest level of parental education and the total annual household income were chosen because the NGHS data were collected at 3 distinct locations with different price indexes, such that the cost of living may have been different in Cincinnati, Ohio, compared with Rockville, Maryland, for example. Age of participants was recorded as that at the most recent birthday.

DAILY CALORIC INTAKE

Daily caloric intake was assessed using a food diary on 3 consecutive days (including 1 day on the weekend and 2 weekdays) concurrent with the recording of physical activity using the accelerometer. Girls were instructed to record all food and drink, the type of meal, and the time of intake. Completed food diaries were reviewed with the girls by certified dieticians, and supplementary information was sought to clarify incomplete responses. Default values from the Nutrition Coordinating Center at the University of Minnesota (Minneapolis) were used for missing information on food amounts, types, and preparation methods. Daily caloric intake was analyzed centrally using a nutrient data system developed by the University of Minnesota.

TELEVISION VIEWING

Hours of television viewing per week were examined by self-report questionnaire. Participants were instructed to circle all programs they usually watched from a list of all television programs available in their area, note the time spent watching music television channels, and list all videos they watched during the past 7 days. The NGHS staff determined the length of each program and video watched and calculated the total television viewing time per week.

STATISTICAL ANALYSIS

Means (SDs) were calculated for continuous variables, and proportions were obtained for categorical variables. We used
tend. A comparison between girls at ages 12 and 14 years who did and who did not provide valid accelerometer data showed that those with valid data were more likely to be white, to have parents with a college degree, to engage in more habitual physical activity, to watch less television per week, and to have lower BMI and body fat (measured using SST).

At age 12 years, the median (interquartile range) levels of objectively measured physical activity were higher in white girls (295.9 [229.2-362.5] accelerometer cpd) than in black girls (253.7 [166.9-334.1] accelerometer cpd) (P < .001) (Table 1). Compared with black girls, white girls had higher levels of habitual physical activity, had parents with higher levels of education, and resided in households with higher total annual incomes. Compared with white girls, black girls had higher BMI and SST, watched more television per week, consumed more total calories per day, and were more likely to have started puberty. Applying the IOTF reference BMI cut points for obesity in children,22 obesity was more common in black girls than in white girls at age 12 years (14.0% vs 4.3%) and at age 14 years (15.6% vs 5.1%) (P < .001). Across white and black girls, high accelerometer cpd were associated with higher levels of self-reported physical activity and were inversely associated with house of television viewing per week (data not shown).

To formally test for differences between black and white girls in associations between quartiles of accelerometer cpd and obesity, we included an interaction term in a minimally adjusted logistic regression model (ie, adjusted for obesity at age 12 years [using CDC, IOTF, or SST criteria] and for age, height, and height squared). Because there was evidence of an interaction on SST (β = 0.20, SE = 10, P = .06) and obesity using IOTF (β = 1.03, SE = 30, P = .001) and CDC criteria (β = 0.53, SE = .13, P < .001), we performed all analyses in black and white girls separately.

Table 3 gives the odds ratios for obesity across quartiles of accelerometer cpd in white and black girls. In the fully adjusted models, the odds ratios for obesity (≥90th percentile for SST) between the top and the bottom quartiles of accelerometer cpd were 0.15 (95% CI, 0.04-0.63; P = .03 for trend) in white girls and 0.85 (95% CI, 0.32-2.26; P = .93 for trend) in black girls. Applying the CDC criterion, the respective odds ratios were 0.040 (95% CI, 0.004-0.300) in white girls and 0.96 (95% CI, 0.27-3.46) in black girls. Using the IOTF cut points, the odds ratios were 0.020 (95% CI, 0.003-0.210) in white girls and 0.92 (95% CI, 0.31-2.71) in black girls.

Among white adolescent girls, we found a strong negative dose-response association between levels of objectively measured physical activity at age 12 years and obesity at age 14 years using the CDC, IOTF, and SST criteria for measuring obesity. The associations between physical activity and obesity were unchanged after considering baseline weight and demographic characteristics. Our results are consistent with those from other prospective cohorts measuring physical activity in children14,29,32 and adolescents30 using accelerometers. Our findings extend these results by suggesting that these associations remain significant after adjusting for variations in sedentary behavior, daily caloric intake, and onset of puberty. We observed no evidence of an association between levels of physical activity and obesity in black girls.

To our knowledge, only one other prospective study16 has measured the association between accelerometer-measured physical activity and obesity in adolescents. Consistent with Riddoch et al,16 we found that the association between overall levels of physical activity and obesity using 3 different measures remained significant when relevant demographic and developmental factors were taken into account. Our finding that this association remained significant after controlling for variations in additional factors associated with weight gain in adolescence (eg, hours of television viewing per week28 and daily caloric intake30) suggests that accelerometers provide valid estimates of energy expenditure.

Black women have some of the highest levels of obesity in the United States,30 and differences in the rates of obesity between white girls and black girls start to emerge in late adolescence.11,31 As such, our finding of no association between physical activity and obesity among black girls herein raises key issues for preventing obesity in this group. Our results are consistent with experiments showing that fat oxidation rates in response to physical activity in black girls during puberty36 and in adult life37 are lower than rates found in white women. These findings indicate that lower fat oxidation rates coupled with lower resting metabolic rates36,37 may predispose black girls to retaining fat accumulated during puberty. Our results suggest that prompting adolescent girls to be active may be important to prevent obesity but that using different ap-
Table 3. Adjusted Odds Ratios for Obesity at Age 14 Years by Quartiles of Accelerometer Counts per Day at Age 12 Years in White and Black Girls

<table>
<thead>
<tr>
<th>Quartile, No. (%)</th>
<th>SST</th>
<th>CDC</th>
<th>IOTF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P Value</td>
<td>Cohen d</td>
</tr>
<tr>
<td>Bottom, 97 (15.9)</td>
<td>1.00 [Reference]</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>Second, 161 (26.4)</td>
<td>0.47 (0.15-1.45)</td>
<td>0.19</td>
<td>-0.60</td>
</tr>
<tr>
<td>Third, 185 (30.3)</td>
<td>0.21 (0.06-0.71)</td>
<td>0.01</td>
<td>-1.32</td>
</tr>
<tr>
<td>Top, 167 (27.4)</td>
<td>0.15 (0.04-0.63)</td>
<td>0.01</td>
<td>-1.72</td>
</tr>
</tbody>
</table>

Abbreviations: CDC, Centers for Disease Control and Prevention criterion; IOTF, International Obesity Task Force criterion; OR, odds ratio; SST, sums of skinfold thickness.

<table>
<thead>
<tr>
<th>Quartile, No. (%)</th>
<th>White Girls (n = 610)</th>
<th>Black Girls (n = 538)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OR (95% CI)</td>
<td>P Value</td>
</tr>
<tr>
<td>Bottom, 172 (32.0)</td>
<td>1.00 [Reference]</td>
<td>...</td>
</tr>
<tr>
<td>Second, 128 (23.8)</td>
<td>0.90 (0.37-2.19)</td>
<td>0.82</td>
</tr>
<tr>
<td>Third, 120 (22.3)</td>
<td>0.72 (0.27-1.89)</td>
<td>0.50</td>
</tr>
<tr>
<td>Top, 118 (21.9)</td>
<td>0.85 (0.32-2.26)</td>
<td>0.76</td>
</tr>
</tbody>
</table>

Our study has several strengths. The data are from a large multicenter study with participants residing in 3 distinct regions of the United States. The study population is a large biracial cohort, enabling comparisons on the effects of physical activity in black and white girls. To our knowledge, this study is the first to investigate differences across black and white girls in the associations between objectively measured physical activity and obesity in free-living adolescents. The use of accelerometers and SST offers more precision than that provided by self-report and helps to differentiate the effects of physical activity on adiposity and lean body mass.

We acknowledge some limitations to our study. First, Caltrac accelerometers were vulnerable to incorrect use, which led to several invalid responses, and are unable to record different intensities of activity. Second, self-reported hours of television viewing per week (such as the measure we used) show low levels of agreement with direct observation of television viewing in adolescent populations. Third, black girls were more likely than white girls at age 12 years to have reached the onset of puberty. Because the onset of puberty has been found to coincide with reduction in physical activity levels among girls, these levels may have already been reduced in black girls before the time of assessment. Although this may have meant that physical activity levels were lower in black girls than in white girls, it is unlikely that this would explain the difference in the observed association between physical activity levels and obesity in black and white girls.

In conclusion, higher levels of physical activity were associated with lower risk of obesity among white girls but not among black girls. Obesity prevention interventions may need to be adapted to account for the finding that black girls are less sensitive to the effects of physical activity. Public health policies to reduce obesity in children should be modified to recognize these differences in metabolism among black and white populations, with strategies on treatment and prevention adapted accordingly.

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Author Contributions: Dr White had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: White and Jago. Acquisition of data: White. Analysis and interpretation of data: White and Jago. Drafting of the manuscript: White and Jago. Critical revision of the manuscript for important intellectual content: White and Jago. Statistical analysis: White.

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Centers Participating in the National Heart, Lung, and Blood Institute Growth and Health Study: Children’s Medical Center at the University of Cincinnati, Cincinnati, Ohio; Stephen R. Daniels, MD, principal investigator, and John A. Morrison, PhD, coinvestigator. Westat, Inc, and...
Group Health Association, Rockville, Maryland: George B. Schreiber, ScD, principal investigator, and Ruth Striegel-Moore, PhD, coinvestigator. University of California, Berkeley: Zak I. Sabry, PhD, principal investigator, and Patricia B. Crawford, DrPH, RD, coinvestigator. The data coordinating center is at the Maryland Medical Research Institute, Baltimore, Maryland (Bruce A. Barton, PhD, principal investigator). The program office is at the National Heart, Lung, and Blood Institute (Eva Obarzanek, PhD, project officer from 1992 to the present, and Gerald H. Payne, MD, project officer from 1985 through 1991). This study was undertaken at the Center for the Development and Evaluation of Complex Interventions for Public Health Improvement, a United Kingdom Clinical Research Collaboration Public Health Research Centre of Excellence.

Disclaimer: The views expressed in this publication are those of the authors and not necessarily those of the National Health Service, the National Institute for Health Research, the Department of Health, the Growth and Health Study, or the National Heart, Lung, and Blood Institute.

REFERENCES


