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ABSTRACT

GORTMAKER, S. L., R. LEE, A. L. CRADOCK, A. M. SOBOL, D. T. DUNCAN, and Y. C. WANG. Disparities in Youth Physical Activity in the United States: 2003–2006. Med. Sci. Sports Exerc., Vol. 44, No. 5, pp. 888–893, 2012. Purpose: This study aimed to examine changes in physical activity among children and adolescents, by race/ethnicity, in the United States from 2003–2004 to 2005–2006. Methods: Secondary analysis of the objectively measured accelerometer data among children and adolescents 6–19 yr: 2003–2004 (n = 1665) and 2005–2006 (n = 1716) from the nationally representative National Health and Nutrition Examination Survey 2003–2004 and 2005–2006. We estimated regression coefficients for change between the two periods by age group, accounting for sampling design and adjusting for age, sex, race/ethnicity, and number of hours monitored. We tested for differences in mean accelerometer counts per minute and minutes per day of moderate and vigorous physical activity trends by race/ethnicity and gender. Results: Physical activity decreased with age, boys were more active than girls, and non-Hispanic black children were more active than non-Hispanic whites (all P < 0.01). Overall mean accelerometer counts increased from 2003–2004 to 2005–2006 for children ages 6–11 yr (+31.6 counts per minute; 95% confidence interval = 0.51–62.6) but not among adolescents ages 12–19 yr. There was an increase over time in mean accelerometer counts among 6- to 11-yr-old non-Hispanic white children (+52.4 counts per minute, P = 0.007; 95% confidence interval = 15.7–89) but a decrease among non-Hispanic black and Mexican American children. No changes over the period in moderate and vigorous physical activity were found in either age group. Conclusions: The lack of improvement in physical activity among all children and adolescents and a potentially emerging race–ethnic disparity indicate a need for further research on potential mechanisms underlying these differences. Effective interventions to improve physical activity opportunities and attenuate the decline in activity levels as children enter adolescence are needed. Key Words: PHYSICAL ACTIVITY LEVELS, ACCELEROMETER, CHILDREN, RACE, ETHNICITY

The prevalence of obesity among boys and girls in the United States has increased at rapid rates with the highest prevalence among non-Hispanic black and Hispanic children and adolescents (22,23,30). This growing epidemic necessitates the identification and monitoring of modifiable behavioral contributors to energy imbalance. The pivotal role of physical activity in weight management among adults is well established (19). Among children and adolescents, in addition to healthier weight gain during growth, the health benefits of achieving recommended physical activity levels include a favorable body composition and improved cardiovascular health and muscular fitness. National guidelines recommend that children and adolescents accumulate ≥60 min of moderate-to-vigorous physical activity (MVPA) every day (36).

Research has consistently documented gender and age disparities in youth physical activity such that boys are more active than girls and children become less active as they grow older (15,20,27,39). There is also some evidence for racial/ethnic disparities in physical activity, but results have been mixed depending on self-report versus accelerometer estimates (39). The available data on trends over time indicate an overall decline in physical activities, including active transport to school (16), self-reported vigorous physical activity (1), and participation in high school physical education (3).

Much of the physical activity data have been traditionally assessed via questionnaires despite limited reliability and validity of self-reported activities, particularly for children (5). Recently, national accelerometer data measuring physical activity levels among US children and adolescents have become available (32). Accelerometers, small devices that
measure minute-to-minute physical movement, are the best available objective and precise measures of free-living activity. Evidence indicates good reliability (18,35) of these devices among children and adolescents, with good evidence for validity against criterion physical activity measures (e.g., direct observation, oxygen consumption \([\text{VO}_2]\), HR, and doubly labeled water) \((7,9,24,35)\).

This study examines changes in physical activity among children and adolescents ages 6–19 yr in the United States from 2003–2004 to 2005–2006, using population-based accelerometer data from the National Health and Nutrition Examination Survey (NHANES), and assesses evidence for differences in these changes by age, gender, and race/ethnicity.

**METHODS**

**Participants.** The NHANES is an ongoing series of nationwide surveys and clinical examinations conducted by the National Center for Health Statistics (NCHS). The surveys use a multistage, clustered, probability sampling strategy to select households and individuals to provide national estimates representative of the civilian noninstitutionalized US population. Non-Hispanic blacks, Mexican Americans, and adolescents ages 12–19 yr are among the oversampled populations. Beginning in 1999, NHANES collected data yearly. This analysis includes two waves, four years of data \((2003–2004\) and \(2005–2006)\) on physical activity level, collected using accelerometers among children and adolescents ages 6–19. More complete description of data collection procedures and analytic guidelines are on the NCHS Web site \((http://www.cdc.gov/nchs/nhanes.htm)\). Informed consent was obtained by the NCHS as part of the NHANES data collection, and the institutional review board at the Harvard School of Public Health determined that, because we were using publicly available data, this work was exempt.

Following the published research of Troiano et al. \((32)\), we included data from children and adolescents ages 6–19 with accelerometer data from these two nationally representative samples. Our change analyses are presented for non-Hispanic white, non-Hispanic black, Mexican American children and adolescents only because of the small sample sizes for other racial/ethnic groups. We defined two age categories: children (ages 6–11) and adolescents (ages 12–19) to make our results comparable to previous research from the same data set and reflect distinct developmental stages. Age, gender, and race/ethnicity were self-reported in home interviews before accelerometer administration. Interviews for participants <16 yr were conducted by a proxy.

**Physical activity assessment.** Measures of physical activity including mean accelerometer counts per minute and minutes per day of MVPA were collected directly after a health examination with the ActiGraph model 7164 accelerometer \((\text{ActiGraph, LLC, Ft. Walton Beach, FL})\) \((4)\). This small uniaxial device measures physical activity intensity by quantifying and recording “counts” of vertical acceleration \((38)\) and was requested to be worn for 7 d \((35)\). The ActiGraph 7164 accelerometer has demonstrated high reliability \((18)\). In addition, the ActiGraph has been validated against criterion measures (e.g., direct observation, oxygen consumption \([\text{VO}_2]\), HR, and doubly labeled water) and correlated with total \((r = 0.39)\) and activity \((r = 0.54)\) energy expenditure as measured by the doubly labeled water \((7)\).

In NHANES, the instrument was programmed to record data continuously at 1-min intervals (or epochs). Participants ages 6 and older were asked to wear an accelerometer on an elasticized belt positioned over their right hip during all waking hours, only removing it for swimming or bathing. Assistants responsible for the medical examination administration fitted the accelerometers to participants and provided initial instructions; further assistance with the activity monitoring protocol was available over a toll-free number. Participants mailed their accelerometers back to NHANES headquarters in a prepaid envelope after the end of 7-d monitoring period \((4)\).

**Accelerometer data processing.** All analysis of accelerometer data followed algorithms developed by Troiano et al. \((32)\), available at the National Cancer Institute Web site \((http://www.riskfactor.cancer.gov/tools/nhanes_pam)\). Following these guidelines, we excluded data from participants whose accelerometers were not calibrated on return. Implausible values, such as long sequences of very high counts, were set to missing. Wear and nonwear times were defined to determine valid days. Nonwear time was defined as a period of at least 60 min of zero intensity counts, allowing for 1- to 2-min spans with counts fewer than 101. Wear time was calculated by subtracting nonwear time from 24 h. A valid day was defined as any day with \(\geq10\) h of wear time \((32)\). Our analyses only included youth with four or more valid days of data consistent with prior recommendations in the literature \((33)\).

Mean counts per minute were calculated by dividing the total counts of activity by the minutes of wear time for all valid days. We applied published age-specific count thresholds obtain from calibration studies by the Freedson group to calculate minutes of MVPA \((34)\) as cited in Troiano et al. \((32)\). We defined MVPA as \(\geq4\) METs in 6- to 17-yr-old participants and 3 METs in 18- and 19-yr-old participants. We used 1-min bouts to calculate total minutes per day of MVPA.

**Statistical analysis.** Analyses were conducted with SAS (Version 9.1; SAS Institute, Cary, NC). We used the procedures SURVEYMEANS and SURVEYREG to account for samples weights and the clustered study design in estimating means and regressions documenting changes in physical activity between the two periods. Sample weights available on the NHANES Web site \((http://www.cdc.gov/nchs/nhanes.htm)\) reflect the unequal probabilities of selection, nonresponse adjustments, and adjustments to independent population control totals.

We stratified by two age groups (ages 6–11 and 12–19 yr) following past research \((32)\) and controlled for age, gender, race/ethnicity, and number of hours monitored on average in...
multivariate regression models. We used indicator variables to indicate the later period (2005–2006 = 1 vs 2003–2004 = 0) and racial/ethnic group (non-Hispanic white as the reference category; with indicators for black non-Hispanic and Mexican American). We also tested for significance of interaction terms of gender (male = 1 vs female = 0) by period as well as race/ethnicity by period. All tests are two-tailed.

RESULTS

We included 1665 children and adolescents (ages 6–19 yr) from NHANES 2003–2004 and 1716 from NHANES 2005–2006. Approximately 75% of the subjects had ≥4 d of valid accelerometer data. Table 1 summarizes the characteristics of the two NHANES samples and the population distributions after applying sampling weights. These estimates show comparable race/ethnicity, gender, and age distributions in 2003–2004 and 2005–2006.

Table 2 displays unadjusted mean accelerometer counts per minute and MVPA counts by age, gender, and race/ethnicity at both periods. Younger children were more physically active than adolescents, and boys were more active than girls (P < 0.01 at both periods).

In the first set of regression models, we adjusted for age, gender, race/ethnicity, and number of hours of monitored time to account for potential differences in the sample composition between the years (Table 3; “partially adjusted models,” models 1 and 2). There was a strong age-dependent decrease in mean counts and MVPA, and the physical activity level was also significantly higher among males (both P < 0.0001).

There was an increase in mean accelerometer counts among children ages 6–11 from 2003–2004 to 2005–2006 (31.6; P = 0.047; 95% confidence interval (CI) = 0.5–62.6) but no significant changes for minutes of moderate and vigorous activity from 2003–2004 to 2005–2006. There were no changes over time in physical activity outcomes among adolescents ages 12–19.

A second set of regression models (Table 3, models 3 and 4) examined changes between NHANES 2003–2004 and 2005–2006 by race/ethnicity. The results indicated an increase in mean accelerometer counts among 6- to 11-yr-old non-Hispanic white children (+52.4 min⁻¹, P = 0.007; 95% CI = 15.7–89) and an increase in minutes of MVPA for this group (+7.9 min⁻¹, P = 0.01; 95% CI = 1.9–13.9).

Conversely, we found a significant interaction for mean accelerometer counts among non-Hispanic black (−64.3; P = 0.05; 95% CI = −125.3 to −3.3) and Mexican American children (−64.1; P = 01; 95% CI = −109.8 to −18.4), indicating no increase in physical activity level among these groups over time (i.e., the negative interaction of −64.3 is added to the coefficient for year of 52.4 to indicate overall no difference). A significant interaction was also found for MVPA among Mexican American children (−9.6; P = 0.02; 95% CI = −17.3 to −1.9), also indicating no overall evidence for change among this group over time. Among 12- to 19-yr-olds, there was no evidence of interaction by race/ethnicity. There were no statistically significant interactions of time with gender for either age group.

DISCUSSION

These nationally representative accelerometer data are the first such objective indicators of population-specific changes in physical activity level in children and adolescents. Among children ages 6–11 yr, there was a small overall increase
in mean accelerometer counts, although we observed these increases only among non-Hispanic white youth and not among Mexican American or non-Hispanic black youth. Because data are currently only available for two periods, the observed changes should be interpreted with caution. Among children, we observed racial-ethnic differences in change in mean accelerometer counts between the two time points as indicated by the significant negative interactions for Hispanic and non-Hispanic black children with period. We did not find significant changes between the time points in mean accelerometer counts or minutes of MVPA among children and adolescents ages 12–19 yr.

It is also important to note the persistent and substantial age and gender differences in physical activity measures with adolescents being markedly less active than children and girls being less active than boys. These results are consistent with a large body of previous research (15,20,27,39) and point to the need for continued monitoring and the implementation of effective interventions that improve physical activity opportunities for girls and attenuate declines in physical activity levels as children enter adolescence.

Although the present analyses are the first to document changes over time in population-specific estimates of physical activity using nationally representative accelerometer data, our results are consistent with earlier evidence for racial/ethnic disparities in self-reported physical activity, including declines over time in physical education class participation (3) and in vigorous physical activity (1) among non-Hispanic blacks. Although an analysis of the NHANES 2003–2004 accelerometer data indicates that young black children were meeting physical activity recommendations at slightly higher rates than white children (39), it is the lack of improvement over time detected for non-Hispanic black and Mexican American children in the present study—a possible emerging disparity in physical activity—that is a cause for concern.

These results can be interpreted in the context of the energy gap that contributes to growing overweight and obesity (37). Using Harrell’s estimate of 1.71 kcal·kg⁻¹·h⁻¹ as the average resting metabolism for children and the average body weight of 30 kg for a typical 9-yr-old boy from the sample, we estimate that the increase in physical activity documented for non-Hispanic white children ages 6–11 represents an increase of about 20.2 kcal·d⁻¹. This level of change, if not accompanied by increased energy intake, could help to offset the average energy gap that has been contributing to growing childhood obesity in the United States (37). The lack of change seen among non-Hispanic black and Hispanic children could, in fact, contribute to growing disparities in childhood obesity.

This study uses objective measures of physical activity obtained using highly reliable accelerometers to produce physical activity estimates that have been validated against energy expenditure using doubly labeled water. The precision of these estimates is higher, and the use of highly reliable and valid measures of physical activity is necessary to detect changes in physical activity over time and thus ascribe causal relationships.

### TABLE 3. Regression estimates from linear models predicting mean accelerometer counts per day and minutes of MVPA per day: NHANES 2003–2004 and 2005–2006.

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Mean Accelerometer Counts—Partially Adjusted Model</th>
<th>MVPA (min)—Partially Adjusted Model</th>
<th>Mean Accelerometer Counts—Fully Adjusted Model</th>
<th>MVPA (min)—Fully Adjusted Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \beta )</td>
<td>SE</td>
<td>( P )</td>
<td>( \beta )</td>
</tr>
<tr>
<td>Age 6–11 yr (n = 1197)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Intercept</td>
<td>1174</td>
<td>78.0</td>
<td>&lt;0.0001</td>
<td>174</td>
</tr>
<tr>
<td>Year 2005–2006 (= 1) vs 2003–2004 (= 0)</td>
<td>31.6</td>
<td>15.2</td>
<td>0.047</td>
<td>4.56</td>
</tr>
<tr>
<td>Male (= 1) vs female (= 0)</td>
<td>83.8</td>
<td>14.2</td>
<td>&lt;0.0001</td>
<td>21.0</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>–41.5</td>
<td>3.20</td>
<td>&lt;0.0001</td>
<td>–16.1</td>
</tr>
<tr>
<td>Mexican American (= 1) vs non-Hispanic white (= 0)</td>
<td>–11.3</td>
<td>12.9</td>
<td>0.38</td>
<td>–2.77</td>
</tr>
<tr>
<td>Non-Hispanic black (= 1) vs non-Hispanic white (= 0)</td>
<td>53.8</td>
<td>17.7</td>
<td>0.005</td>
<td>9.90</td>
</tr>
<tr>
<td>Year 2005–2006 vs Mexican American</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2005–2006 vs non-Hispanic black</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean wear (h·d⁻¹)</td>
<td>–19.3</td>
<td>5.96</td>
<td>0.003</td>
<td>2.71</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.19</td>
<td></td>
<td></td>
<td>0.46</td>
</tr>
<tr>
<td>Age 12–19 yr (n = 2184)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>715</td>
<td>60.1</td>
<td>&lt;0.0001</td>
<td>25.5</td>
</tr>
<tr>
<td>Year 2005–2006 (= 1) vs 2003–2004 (= 0)</td>
<td>–11.5</td>
<td>13.3</td>
<td>0.39</td>
<td>–1.85</td>
</tr>
<tr>
<td>Male (= 1) vs female (= 0)</td>
<td>118</td>
<td>7.97</td>
<td>&lt;0.0001</td>
<td>16.3</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>–16.2</td>
<td>1.94</td>
<td>&lt;0.0001</td>
<td>–1.70</td>
</tr>
<tr>
<td>Mexican American (= 1) vs non-Hispanic white (= 0)</td>
<td>15.0</td>
<td>10.3</td>
<td>0.15</td>
<td>4.56</td>
</tr>
<tr>
<td>Non-Hispanic black (= 1) vs non-Hispanic white (= 0)</td>
<td>21.7</td>
<td>9.56</td>
<td>0.03</td>
<td>4.58</td>
</tr>
<tr>
<td>Year 2005–2006 vs Mexican American</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2005–2006 vs non-Hispanic black</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean wear (h·d⁻¹)</td>
<td>–8.01</td>
<td>3.01</td>
<td>0.013</td>
<td>1.53</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.17</td>
<td></td>
<td></td>
<td>0.16</td>
</tr>
</tbody>
</table>

* Partially adjusted models control for period, race/ethnicity, age, and average hours of wear per day.

\* Fully adjusted models control for period, race/ethnicity, age, and average hours of wear per day and include interaction term for race/ethnicity by period.
physical activity (e.g., weight lifting). In addition, the 1-min epoch used to collect accelerometer data may underestimate activity levels for very young children because their activities often occur in relatively short bursts rather than in long bouts (2). The analysis also does not capture whether children had any activity-limiting ailments or disabilities. Although we recognize the effect of income and other measures of socioeconomic status on physical activity, we chose to focus on race/ethnicity because family income frequently shifts across time and has a complex relationship with race/ethnicity along the pathway to disease and health behavior. Seasonality may have effects on the physical activity pattern among children and adolescents. We explored this effect on our results by including a variable indicating whether a child is on school vacation between grades (generally indicating summer vacation). However, our estimates did not change nor did it increase the goodness of fit statistic ($R^2$; data not shown).

Lastly, these data represent national physical activity patterns from 2003 to 2006. Future studies will benefit from a longer data series to document population-specific trends in physical activity patterns using accelerometer data from future NHANES studies.

Although this study does not examine how potential differences in physical activity among racial/ethnic populations may be emerging, differential access to resources, recent changes in the US school climate and an increase in obesity prevention efforts including more physical activity in more privileged communities may help to explain these potential disparities (6,10,11,26,29). Racial/ethnic minority children have reduced access to physical activity resources (e.g., recreational facilities, parks, playgrounds) and reduced access to safe playgrounds (6,8,11). Moreover, neighborhood factors through the built environment (such as safety and walkability) may be particularly large influences due to the persistence of racial segregation in the United States (17,25,40).

The initiation of No Child Left Behind in 2001 has steadily shifted the focus of public schools to standardized test achievement, and this focus has often led to declines in funding for physical education, recess, and other school-day determinants of physical activity levels (29). Recent studies have found racial differences in school sports participation, required physical education, and girls’ physical activity levels in school (14,26). Because low-income and racial/ethnic minority children get a larger percentage of their daily physical activity within school settings, they are likely differentially affected by recent changes in school climate (13). Finally, because knowledge of the obesity epidemic has grown and become a national priority during the past decade, it is possible that white children have been the early benefactors of physical activity interventions and programs within the community (10).

This evidence documenting a small overall change over time in physical activity levels and disparities in activity patterns documents the need for continued focus on increasing opportunities for physical activity among children and adolescents. Interventions targeted to racial/ethnic minority children and adolescents at the policy, environment, and school levels have promise of reducing physical activity and obesity-related disparities (39). The Task Force for Community Preventive Services recommends increasing time in school-based physical education, urban design and land-use policies at the community and street levels, as well as enhanced access to places for physical activity with information outreach as promising strategies for promoting physical activity (12,31). Federal policies that require and enforce regular K-12 physical education and comprehensive school wellness policies can promote school environments that support physical activity (29). Community change efforts can focus on creating and restoring environments that are supportive of physical activity, which include safe parks, playground, recreation areas and sidewalks (28). Particular focus can be given to aesthetic and safety improvements because these may address barriers to physical activity in otherwise walkable, urban areas in poorer communities (21).

The recent nationally representative accelerometer data suggest increases in overall accelerometer counts of physical activity among non-Hispanic white children 6–11 yr, but not among Mexican Americans and non-Hispanic blacks. The insights gleaned from this study may help target prevention efforts and provide useful information to ameliorate racial/ethnic disparities in physical activity. Our results document the need to develop interventions that can address these emerging disparities, improve physical activity opportunities for girls, and attenuate the decline in activity levels as children enter adolescence.

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- The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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