Physical Activity in the United States Measured by Accelerometer

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ABSTRACT

TROIANO, R. P., D. BERRIGAN, K. W. DODD, L. C. MÂSSE, T. TILERT, and M. MCDOWELL. Physical Activity in the United States Measured by Accelerometer. *Med. Sci. Sports Exerc.*, Vol. 40, No. 1, pp. 181–188, 2008. **Purpose:** To describe physical activity levels of children (6–11 yr), adolescents (12–19 yr), and adults (20+ yr), using objective data obtained with accelerometers from a representative sample of the U.S. population. **Methods:** These results were obtained from the 2003–2004 National Health and Nutritional Examination Survey (NHANES), a cross-sectional study of a complex, multistage probability sample of the civilian, noninstitutionalized U.S. population in the United States. Data are described from 6329 participants who provided at least 1 d of accelerometer data and from 4867 participants who provided four or more days of accelerometer data. **Results:** Males are more physically active than females. Physical activity declines dramatically across age groups between childhood and adolescence and continues to decline with age. For example, 42% of children ages 6–11 yr obtain the recommended 60 $min \cdot d^{-1}$ of physical activity, whereas only 8% of adolescents achieve this goal. Among adults, adherence to the recommendation to obtain 30 $min \cdot d^{-1}$ of physical activity is less than 5%. **Conclusions:** Objective and subjective measures of physical activity give qualitatively similar results regarding gender and age patterns of activity. However, adherence to physical activity recommendations according to accelerometer-measured activity is substantially lower than according to self-report. Great care must be taken when interpreting self-reported physical activity in clinical practice, public health program design and evaluation, and epidemiological research. **Key Words:** NHANES, MODERATE, VIGOROUS, BOUTS, YOUTH, ADULTS

It has been more than 10 yr since the publication of the Surgeon General's Report on Physical Activity and Health (31) and the CDC/ACSM recommendations to accumulate at least 30 min of moderate-intensity physical activity on most days of the week (17). During that time, the prevalence of overweight and obesity has increased among every segment of the U.S. population (16), as well as among residents of countries around the world (18,34). In considering why obesity has become a global problem, the focus has shifted from diet alone to the balance between diet and physical activity (12,13). In addition to its role in energy balance, evidence for the health benefits of physical activity continues to accrue (32).

In the United States and many other countries, population data on physical activity are collected in national health surveys through self- or proxy-reports (28). These adult population physical activity data are categorized into *no leisure-time physical activity*, *some physical activity*, and *sufficient physical activity to meet recommended levels,* with 20–40% in each category (28). Self-report of physical activity suffers from significant reporting bias (20) attributable to a combination of social desirability bias and the cognitive challenge associated with estimating frequency and duration of physical activity for adults and, especially, children (8). Furthermore, population surveys are limited in the number of questions used to assess a specific behavior. Objective measurement devices such as pedometers, which measure steps, and accelerometers, which measure movement intensity, offer a potential solution to problems with self-reported data (1,27). These devices are small, can store data for multiple days, and are increasingly reliable and affordable.

In 2003, with support from the National Cancer Institute of the National Institutes of Health, objective assessment of

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physical activity with accelerometers was implemented in the National Health and Nutrition Examination Survey (NHANES). The accelerometer data from NHANES 2003–2004 provide the first objective measures of physical activity for the U.S. population. The purpose of this study is to describe levels of measured physical activity in the United States and to contrast estimates of adherence to recommended levels of physical activity assessed by accelerometer with those from self-reports.

METHODS

NHANES 2003–2004 included a representative sample of the U.S. civilian noninstitutionalized population selected with a complex, multistage probability design.

Briefly, survey participants were interviewed in their homes (1–2 h) and subsequently examined in mobile examination centers (MEC). The health examination lasted approximately 3–4 h, and examinees received remuneration for their participation. Each MEC had a staff of 16, including health technicians, health and dietary interviewers, a physician, a field engineer, and administrative personnel. The NCHS ethics review board approved the survey protocols, and informed consent was obtained for all subjects. All survey materials were produced in English and Spanish languages, and bilingual staff conducted the health interviews and examinations. NHANES operates year-round. Fifteen geographic locations are selected annually. The survey teams spend several weeks at each site to collect the interview and health examination data. Because of logistical issues for field staff and the MEC, the colder regions of the country are scheduled during the warmer months of the year. During NHANES 2003–2004, a total of 9643 individuals (all ages) were interviewed and examined. Standardized data-collection methods are used in NHANES to minimize site-specific error and interexaminer bias (7).

For the physical activity monitor component, all ambulatory examined participants ages 6 yr and older were asked to wear an Actigraph (Actigraph, LLC; Ft. Walton Beach, FL) model 7164 accelerometer over the right hip on an elasticized belt for the 7 d after their examination. Participants were asked to wear the device while they were awake and to take it off for swimming or bathing. Monitors were returned by express mail to the NHANES contractor, where data were downloaded and the device was checked to determine whether it was still within the manufacturer's calibration specifications, using an Actigraph calibrator. Details of the accelerometer protocol are available (5). The uniaxial Actigraph measures and records vertical acceleration as "counts," providing an indication of the intensity of physical activity associated with locomotion (33). Data were recorded in 1-min epochs for up to 1 wk.

Data analysis. Accelerometer data were obtained from 7176 individuals. Participants whose monitors were not in calibration on return ($N = 344$) were excluded. Questionable portions of data for 86 participants were set to missing. The affected values were extended sequences of the maximum recordable value, or sequences of 60+ min in which activity never returned to zero. For the analyses presented here, a valid day was defined as having 10 or more hours of monitor wear. *Wear time* was determined by subtracting nonwear time from 24 h. *Nonwear* was defined by an interval of at least 60 consecutive minutes of zero activity intensity counts, with allowance for 1–2 min of counts between 0 and 100. This resulted in 4867 participants who had four or more valid days of monitor wear, and 6329 participants with one or more valid days. Data for participants with four or more valid days are described throughout the paper, whereas the 6329 participants with one or more valid days are used only for population adherence estimates.

NHANES-provided sample weights allow valid population estimates for defined demographic groups. Potential selection bias attributable to lack of sufficient valid accelerometer data was examined by comparing measured anthropometric (height, weight, body mass index, overweight, obese) characteristics of participants with four or more valid days against the characteristics of those who did not meet this criterion. Among children (ages 6–11 yr), no differences attributable to the selection were observed. However, among adolescents and adults, sufficient differences in body weight status existed to justify reweighting the sample. Sample weights were recalculated from the raw NHANES weights to reflect the additional "nonresponse" related to not having complete accelerometer data. This reweighting within age, gender, and racial/ethnic groups seemed to correct for potential selection bias for the subsamples with either four or more valid days or one or more valid days, according to the same comparison of anthropometric data.

Outcomes. The amount of physical activity as measured by accelerometer is presented in three ways: 1) mean counts per minute, 2) estimates of the time spent in physical activity according to count thresholds, 3) and an estimate of adherence to physical activity recommendations.

Mean counts per minute evaluate the raw data provided by the accelerometer without imposition of any external criteria other than determination of wear and nonwear time. Mean counts per minute were calculated by dividing the sum of activity counts for a valid day by the number of minutes of wear time in that day across all valid days.

Time spent in physical activity of moderate or vigorous intensity, separately or combined, is based on application of count thresholds corresponding to moderate- or vigorous-intensity activity. These thresholds are obtained from calibration studies that relate accelerometer counts to measured activity energy expenditure. For adults and older adolescents (ages 18 or older), intensity thresholds were calculated as a weighted average of criteria determined from four studies that based criteria on treadmill or track walking (4,10,14,35). The resulting intensity-threshold criteria were 2020 counts for moderate intensity (equivalent to 3 METs)

and 5999 counts for vigorous intensity (6 METs). For youth ages 6–17 yr, the age-specific criteria of the Freedson group, as published by Trost et al. (29), were used with thresholds for moderate activity of 4 METs and vigorous activity of 7 METs. This adjusts for the higher resting energy expenditure of children and youth (11,19). The specific criteria for each age are specified in the SAS code available at http://riskfactor.cancer.gov/tools/nhanes_pam (15).

Time spent in activity of a defined intensity (moderate, vigorous, or moderate and vigorous combined) was determined by summing minutes in a day where the count met the criterion for that intensity. To reflect accumulation of activity that might be important for energy balance, time spent in physical activity is presented for every minute that meets the specific criterion. Duration data are also presented for activity occurring in sustained bouts. For comparison with physical activity recommendations, 10-min activity bouts were defined as 10 or more consecutive minutes above the relevant threshold, with allowance for interruptions of 1 or 2 min below threshold. This is referred to as a modified 10-min bout. A bout was terminated by 3 min below threshold. Mean daily time in bouts was calculated across all valid days.

Finally, adherence to physical activity recommendations was examined by estimating the proportion of the population that meets the published physical activity guidelines to accumulate 30 min of at least moderate-intensity activity (for adults) or 60 min (for youth) on most days of the week (17,31). Adults were considered to meet the recommendation if they accumulated at least 30 min of moderate- or greater-intensity activity in modified 10-min bouts on 5 of 7 d. For youth ages 6–15 yr, the recommendation is to accumulate 60 min of at least moderate-intensity physical activity per day. For children, every minute above the age-specific criterion for moderate intensity was included. For older adolescents, ages 16–19 yr, prevalence was calculated both by including every moderate or greater minute and by restricting inclusion to bouts.

To maximize the sample size to estimate adherence prevalence (important because only 26% of the sample had seven valid days of wear), a Bayesian approach was used to incorporate the information from all individuals with one or more valid days (2). In this approach, the probability (P) that a particular individual obtains the recommended physical activity on a given day is unknown, but it is assumed to lie somewhere between 0 and 1. Additionally, the x out of n days on which the accelerometer was worn ("trials") is assumed to be a binomial random variable. Using Bayes' theorem, the probability that someone with x out of n active days is adherent (has $P \geq 5/7$) can be calculated for individuals with any number of days of accelerometer wear. The estimated population prevalence of adherence, p_a, is the weighted average of the adherence probabilities where the weights are the estimated population prevalence of each possible combination of adherence and wear days. (Detailed derivation and SAS code are available at http://riskfactor.cancer.gov/tools/nhanes_pam (15).) This process results in the estimated prevalence of adherence based on the 6329 participants with one or more valid days of accelerometer data.

All analyses were conducted with SAS and SUDAAN to account for the complex survey design used in NHANES (22,23). Age and racial/ethnic groups were categorized according to NHANES analytic guidelines (6). Adjusted sample weights for subsamples with either one or more or four or more valid days were used for all analyses. Planned comparisons of counts per minute and duration of moderate- or greater-intensity activity among racial/ethnic groups were made with pairwise contrasts. Significance was assessed with a two-sided t-test with alpha = 0.05 and 15 df. Degrees of freedom were based on the number of primary sampling units in NHANES (6).

RESULTS

Demographic and anthropometric characteristics of the study population are presented in Table 1. The analyzed sample included 68% of the eligible sample of 7176 participants. The sample response rates for number of days of monitor wear for the 6830 persons with any accelerometer

TABLE 1. Characteristics (mean and SEM) of the reweighted analyzed sample.

	6–11 yr		12–19 yr		20–59 yr		60+yr	
Variable*	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**	**Male**	**Female**
N	309	288	570	611	936	892	636	624
Age (yr)	8.4 (0.1)	8.5 (0.1)	15.3 (0.2)	15.0 (0.1)	39.5 (0.5)	39.2 (0.5)	71.1 (0.4)	70.4 (0.2)
Race/ethnicity								
Non-Hispanic white (%)	60.2 (5.4)	62.1 (6.3)	65.4 (5.0)	62.3 (5.3)	72.1 (3.8)	73.6 (3.3)	83.7 (3.3)	84.3 (3.8)
Non-Hispanic black (%)	14.6 (3.3)	15.7 (2.8)	15.6 (2.0)	16.8 (3.0)	10.9 (1.9)	8.9 (1.6)	7.2 (2.1)	7.3 (1.6)
Mexican American (%)	15.4 (3.3)	13.8 (4.0)	13.5 (3.4)	13.0 (2.9)	8.0 (2.0)	9.6 (2.3)	3.2 (1.7)	3.7 (1.9)
Other (%)	9.9 (2.7)	8.4 (2.4)	5.5 (1.7)	7.8 (1.9)	9.0 (1.3)	7.8 (1.4)	5.8 (0.9)	4.7 (1.6)
Height (cm)	135.5 (0.8)	133.6 (1.0)	159.8 (0.9)	168.8 (0.7)	161.1 (0.9)	175.7 (0.7)	158.0 (1.0)	173.2 (0.9)
Weight (kg)	35.9 (0.8)	34.0 (0.8)	61.3 (1.0)	66.2 (1.0)	73.6 (0.9)	87.4 (1.0)	71.8 (0.7)	86.5 (0.9)
BMI ($kg \cdot m^{-2}$)	18.9 (0.3)	18.1 (0.3)	23.6 (0.3)	22.8 (0.3)	27.6 (0.3)	27.8 (0.3)	27.7 (0.2)	28.1 (0.3)
At risk of overweight† (%)	19 (3)	14 (2)	18 (2)	19 (3)				
Overweight† (%)	17 (2)	17 (2)	17 (2)	17 (2)				
Overweight (BMI = 25.0–29.9, %)					27 (2)	39 (2)	38 (3)	47 (3)
Obese (BMI ≥ 30, %)					31 (2)	30 (3)	30 (2)	28 (2)

* Values weighted to account for the survey design, component noncompliance, and inclusion in the analytic sample with four or more valid days; SEM in parentheses.
† Definitions based on comparison with CDC growth charts: overweight = BMI ≥ 95th percentile; at risk of overweight = 85th percentile ≤ BMI < 95th percentile.

TABLE 2. Sample response rates for number of days wearing accelerometer, by age and gender.

Age (yr)	Gender	Number of Valid Days* of Accelerometer Wear (%)							
		0	1	2	3	4	5	6	7
6–11	Male	4.9	9.4	6.2	8.6	13.3	12.8	21.4	23.4
	Female	4.7	6.5	7.4	12.1	11.0	17.5	22.2	18.6
12–19	Male	9.0	7.4	10.8	10.7	12.1	15.0	18.2	16.8
	Female	10.2	8.2	9.2	10.3	14.1	12.5	18.6	16.8
20–39	Male	10.0	6.8	7.4	9.4	10.8	16.8	18.7	19.9
	Female	13.3	10.3	7.4	8.6	11.2	15.8	17.5	15.9
40–59	Male	5.2	3.3	4.2	6.9	6.8	16.3	25.1	32.2
	Female	5.6	3.8	4.9	7.2	10.5	16.3	20.7	30.9
60+	Male	2.7	3.6	3.8	4.4	5.9	10.8	22.5	46.3
	Female	3.6	3.2	4.0	4.9	7.2	11.4	20.8	45.0

* A valid day was defined as having 10 or more hours of accelerometer wear.

data are shown in Table 2. Adults over age 60 yr had the highest wearing compliance, with more than 84% having four or more days. Adolescents (12–19 yr) and females ages 20–39 yr were noticeably less compliant, with approximately 60–62% having four or more days. The mean daily accelerometer wear time within the analyzed sample with four or more valid days was 14.2 h. When examined by age groups, the lowest wear time was 13.7 h for ages 6–11 yr, and the highest was 14.5 h for ages 40–49 yr (data not shown).

Activity counts. Mean counts per minute (Table 3) during wear time were consistently higher for males than females, except in the 60- to 69-yr age group, where mean values for males and females were similar. Mean counts declined with age, particularly from childhood through adolescence. Among youth, there were no consistent differences among racial/ethnic groups. However, among adults, Mexican American men and women had higher mean counts than did non-Hispanic white or non-Hispanic black men and women.

Activity duration. Table 4 presents mean minutes per day above the specified cut points for moderate- or vigorous-intensity activity, as well as any activity of moderate or greater intensity (combined). Data are presented for every minute exceeding the relevant cut point and for activity occurring in modified 10-min bouts. Children (ages 6–11 yr) obtained 10–16 min of vigorous activity per day, but adults obtained less than 2 $min \cdot d^{-1}$. For those over age 60 yr, mean time in vigorous-intensity activity did not differ from zero. When only bouts of vigorous activity are counted, the mean time was generally less than 1 $min \cdot d^{-1}$ among adults.

Children of both sexes obtained more than 1 $h \cdot d^{-1}$ of physical activity above the moderate cut point, but for ages 16–19 yr the average time dropped to 33 min for males and 20 min for females. The mean time remained fairly stable for adults through age 40–49 yr and then declined further with increasing age. When only bouts of activity were counted, boys and girls ages 6–11 yr accumulated 45 and 26 min of moderate- or greater-intensity activity per day, respectively. For ages 16–19 yr, the corresponding time dropped to 11 and 6 min. Adults obtained only 6–10 $min \cdot d^{-1}$ of moderate- or greater-intensity activity per day through ages 60–69 yr.

Mean duration of physical activity among racial/ethnic groups also varied by age. Among children, non-Hispanic blacks tended to have higher minutes per day than other groups, but the differences between racial/ethnic groups were not consistently significant. There were no clear racial/ethnic differences among adolescents. Among adults, Mexican American men had the highest duration of moderate or greater activity when every minute was counted, but not in bouts of activity.

Prevalence of adherence to physical activity recommendations. Estimated prevalence of adherence to current physical activity recommendations is shown for adults and youth in Table 5. Adults met the recommendation

TABLE 3. Mean (SEM) accelerometry counts per minute during wear time by gender, age, and race/ethnicity.

	Males		Females	
	N	Mean (SEM)	*N*	Mean (SEM)
Age				
6–11	288	646.5 (20.9)	309	567.6 (11.9)
12–15	344	521.0 (24.1)	308	381.6 (13.7)
16–19	267	428.9 (11.3)	262	327.8 (12.1)
20–29	212	423.6 (12.6)	219	327.2 (6.9)
30–39	217	444.2 (13.4)	240	333.6 (8.6)
40–49	259	386.5 (11.3)	258	311.4 (8.1)
50–59	204	338.2 (11.3)	219	271.6 (7.8)
60–69	269	256.7 (8.8)	287	251.2 (6.8)
70+	355	188.9 (5.4)	349	169.8 (3.0)
Race/ethnicity*				
Ages 6–11 yr				
Non-Hispanic white	79	632.1 (26.7)[a]	82	560.1 (13.6)[a,b]
Non-Hispanic black	104	722.4 (28.3)[b]	102	609.0 (27.3)[a]
Mexican American	89	673.1 (25.0)[a,b]	110	543.1 (15.5)[b]
Ages 12–15 yr				
Non-Hispanic white	85	507.8 (28.6)[a]	74	378.1 (17.6)[a]
Non-Hispanic black	127	555.0 (32.2)[a]	104	381.8 (13.1)[a]
Mexican American	116	524.4 (21.3)[a]	121	383.4 (16.5)[a]
Ages 16–19 yr				
Non-Hispanic white	63	413.5 (16.1)[a]	74	328.5 (18.2)[a]
Non-Hispanic black	109	474.9 (12.2)[b]	90	322.7 (11.9)[a]
Mexican American	85	483.1 (16.4)[b]	82	357.7 (17.1)[a]
Ages 20–59 yr				
Non-Hispanic white	465	385.7 (8.0)[a]	502	309.7 (5.0)[a]
Non-Hispanic black	174	401.0 (13.4)[a]	181	308.2 (9.6)[a]
Mexican American	191	496.8 (14.2)[b]	182	343.3 (5.5)[b]
Ages 60 yr and older				
Non-Hispanic white	384	221.6 (6.3)[a]	385	208.7 (5.2)[a]
Non-Hispanic black	81	215.4 (10.1)[a]	83	192.0 (8.7)[a]
Mexican American	134	283.5 (17.5)[b]	137	214.6 (9.2)[a]

* "Other" race/ethnicity is included in age classifications, but not examined as a separate group.
[a, b] Racial/ethnic groups with different letters differ at $P < 0.05$.

TABLE 4. Mean (SEM) minutes per day above specified cut points* for moderate and vigorous activity overall and in modified bouts of 10+ min.

	Males			Females		
	Moderate	Vigorous	Combined	Moderate	Vigorous	Combined
Overall (includes every minute over cut point)						
Age						
6–11	79.5 (3.7)	16.0 (1.3)	95.4 (4.7)	65.1 (1.6)	10.1 (0.6)	75.2 (2.0)
12–15	39.2 (2.7)	6.0 (0.7)	45.3 (3.4)	21.7 (1.4)	2.9 (0.5)	24.6 (1.8)
16–19	29.8 (2.1)	3.0 (0.3)	32.7 (2.2)	18.5 (2.3)	1.1 (0.3)	19.6 (2.4)
20–29	37.9 (1.9)	1.9 (0.3)	39.7 (2.0)	22.4 (1.0)	1.3 (0.3)	23.6 (1.1)
30–39	41.3 (2.0)	1.6 (0.4)	42.8 (2.1)	19.9 (1.4)	1.4 (0.3)	21.3 (1.5)
40–49	33.4 (1.7)	1.3 (0.2)	34.7 (1.7)	19.3 (1.3)	0.5 (0.1)	19.9 (1.2)
50–59	25.3 (1.4)	1.1 (0.3)	26.4 (1.5)	15.0 (1.3)	0.4 (0.2)	15.4 (1.4)
60–69	16.3 (1.1)	0.4 (0.2)	16.7 (1.2)	12.3 (0.9)	0.1 (0.0)	12.4 (0.9)
70+	8.6 (0.7)	0.1 (0.0)	8.7 (0.7)	5.4 (0.4)	0.0 (0.0)	5.4 (0.3)
Race/ethnicity†						
Ages 6–11 yr						
Non-Hispanic white	78.0 (5.2)	14.4 (1.7)	92.3 (6.3)[a]	63.6 (2.8)	9.5 (0.5)	73.1 (3.2)[a,b]
Non-Hispanic black	92.3 (3.9)	21.7 (1.2)	114.0 (5.0)[b]	75.8 (5.7)	11.6 (0.9)	87.4 (6.2)[a]
Mexican American	79.5 (3.1)	17.5 (1.9)	97.0 (4.6)[a]	61.9 (2.7)	8.9 (1.1)	70.8 (3.4)[b]
Ages 12–15 yr						
Non-Hispanic white	35.6 (2.5)	5.4 (0.9)	41.0 (3.4)[a]	23.9 (2.3)	2.4 (0.4)	22.4 (2.0)[a]
Non-Hispanic black	46.5 (4.8)	7.6 (0.6)	54.1 (5.2)[b]	21.0 (2.1)	1.6 (0.3)	26.4 (2.6)[a]
Mexican American	43.2 (3.1)	7.4 (0.8)	50.6 (3.8)[a,b]	24.1 (2.0)	2.8 (0.7)	26.9 (2.6)[a]
Ages 16–19 yr						
Non-Hispanic white	26.5 (2.4)	2.8 (0.6)	29.3 (2.7)[a]	17.9 (3.0)	1.1 (0.4)	19.1 (3.1)[a]
Non-Hispanic black	38.3 (3.4)	4.1 (0.6)	42.5 (3.6)[b]	17.4 (2.2)	0.6 (0.3)	18.1 (2.4)[a]
Mexican American	38.5 (3.4)	2.6 (0.6)	41.0 (3.3)[b]	23.4 (3.4)	2.3 (0.5)	25.7 (3.4)[a]
Ages 20–59 yr						
Non-Hispanic white	33.2 (1.2)	1.4 (0.3)	34.6 (1.2)[a]	18.6 (0.8)	1.1 (0.2)	19.7 (0.9)[a]
Non-Hispanic black	36.2 (2.6)	1.8 (0.4)	37.9 (2.7)[a]	19.4 (2.2)	0.6 (0.2)	20.0 (2.2)[a]
Mexican American	44.1 (2.4)	1.6 (0.5)	45.7 (2.4)[b]	21.7 (1.0)	0.4 (0.2)	22.1 (1.0)[a]
Ages 60 yr and older						
Non-Hispanic white	12.1 (0.7)	0.3 (0.1)	12.4 (0.8)[a]	8.7 (0.6)	0.1 (0.0)	8.8 (0.6)[a]
Non-Hispanic black	10.8 (1.0)	0.0 (0.0)	10.9 (1.0)[a]	5.8 (0.8)	0.0 (0.0)	5.9 (0.8)[b]
Mexican American	18.1 (2.1)	0.3 (0.1)	18.4 (2.2)[b]	8.2 (1.2)	0.0 (0.0)	8.3 (1.2)[a,b]
In modified bouts of 10 min or more						
Age						
6–11	22.4 (2.2)	4.2 (0.7)	45.1 (3.9)	12.8 (0.6)	1.8 (0.3)	26.2 (1.3)
12–15	11.6 (1.4)	1.4 (0.3)	18.6 (2.3)	4.4 (0.4)	0.9 (0.4)	7.1 (0.9)
16–19	7.7 (0.9)	0.9 (0.3)	10.9 (1.1)	4.2 (1.1)	0.4 (0.2)	5.5 (1.3)
20–29	8.3 (0.8)	0.9 (0.3)	10.3 (1.0)	5.8 (0.7)	0.7 (0.2)	7.4 (0.8)
30–39	8.0 (0.9)	0.7 (0.3)	9.9 (1.4)	4.8 (0.9)	1.2 (0.3)	6.5 (1.1)
40–49	7.9 (0.9)	0.8 (0.1)	9.3 (0.8)	5.9 (0.8)	0.4 (0.1)	6.6 (0.8)
50–59	5.7 (1.0)	0.9 (0.3)	7.1 (1.2)	5.2 (0.8)	0.2 (0.2)	5.7 (0.9)
60–69	6.0 (1.0)	0.2 (0.1)	6.5 (1.1)	5.7 (0.8)	0.0 (0.0)	5.8 (0.9)
70+	3.5 (0.4)	0.1 (0.0)	3.5 (0.4)	2.2 (0.4)	0.0 (0.0)	2.2 (0.4)
Race/ethnicity†						
Ages 16–19 yr						
Non-Hispanic white	5.9 (0.9)	0.9 (0.4)	8.8 (1.2)[a]	3.9 (1.5)	0.4 (0.3)	5.2 (1.7)[a,b]
Non-Hispanic black	12.1 (1.8)	1.1 (0.4)	17.2 (2.2)[b]	3.4 (0.7)	0.1 (0.1)	4.1 (1.0)[a]
Mexican American	11.2 (2.3)	0.7 (0.2)	14.0 (2.2)[a,b]	5.4 (1.2)	1.3 (0.5)	8.2 (1.4)[b]
Ages 20–59 yr						
Non-Hispanic white	7.1 (0.7)	0.8 (0.2)	8.8 (0.9)[a]	5.2 (0.6)	0.8 (0.2)	6.5 (0.7)[a]
Non-Hispanic black	9.0 (1.6)	0.8 (0.4)	11.0 (1.8)[a]	6.2 (1.3)	0.4 (0.1)	6.8 (1.3)[a]
Mexican American	8.8 (0.9)	0.8 (0.3)	10.5 (0.8)[a]	5.6 (0.6)	0.1 (0.0)	6.1 (0.5)[a]
Ages 60 yr and older						
Non-Hispanic white	4.6 (0.6)	0.1 (0.0)	4.9 (0.6)[a]	3.9 (0.5)	0.0 (0.0)	4.0 (0.5)[a]
Non-Hispanic black	2.6 (0.6)	0.0 (0.0)	2.6 (0.6)[b]	1.0 (0.3)	0.0 (0.0)	1.1 (0.3)[b]
Mexican American	6.7 (1.1)	0.1 (0.1)	7.1 (1.2)[a]	3.0 (0.7)	0.0 (0.0)	3.0 (0.7)[a]

* Adherence definitions were based on age-specific criteria for moderate and vigorous intensity for ages 6–17 yr; moderate-intensity criterion = 2020 and vigorous-intensity criterion = 5999 counts per minute for ages 18 and older.

† "Other" race/ethnicity is included in age classifications, but not examined as a separate group.

[a, b] Racial/ethnic groups with different letters differ at $P < 0.05$.

by accumulating bouts of activity to achieve 30 or more minutes of at least moderate-intensity physical activity on 5 or more days out of 7 d. Youth met the recommendation by accumulating 60 or more minutes of at least moderate-intensity activity, including every minute above the criterion level, on 5 or more days out of 7 d. Prevalence for ages 16–19 yr is shown when every minute is included, as well as when only modified 10-min bouts are counted. Among children, 42% achieved the recommended amount of physical activity, as measured by accelerometer. Interestingly, gender differences in adherence were observed even in the youngest age group, with 48% of boys obtaining at least 60 min compared with 35% of girls. The prevalence of adherence was only 6–8% among adolescents, and less than 5% among adults. The gender difference increased during adolescence. For ages 12–15 yr, adherence prevalence for boys was 12%—about a quarter of the prevalence for ages 6–11 yr. Adherence prevalence for

TABLE 5. Prevalence* (% and SE) of the population attaining sufficient† physical activity to meet public health recommendations.

Approach	Age (yr)	Males	Females	Total
Counting every minute	6–11	48.9 (2.8)	34.7 (1.2)	42.0 (1.6)
	12–15	11.9 (1.7)	3.4 (0.6)	8.0 (1.1)
	16–19	10.0 (1.6)	5.4 (1.4)	7.6 (1.2)
Counting only bouts	16–19	7.1 (1.0)	4.1 (1.0)	5.6 (0.8)
	20–59	3.8 (0.4)	3.2 (0.3)	3.5 (0.3)
	60+	2.5 (0.4)	2.3 (0.5)	2.4 (0.4)

* Prevalence estimates were based on individuals with one or more valid days of accelerometer data. Adherence definitions were based on age-specific criteria for moderate intensity for ages 6–17 yr; moderate-intensity criterion = 2020 counts per minute for ages 18 and older.

† Adherence: for ages 6–19 yr, 60 or more minutes of moderate- or greater-intensity activity on 5 of 7 d, accumulating every minute above criterion; for ages 16 yr and older, 30 or more minutes of moderate- or greater-intensity activity on 5 of 7 d, accumulated in modified 10-min bouts (8 of 10 min). Ages 16–19 yr were estimated with both definitions.

12- to 15-yr-old girls was only 3%—a 10th of the value for ages 6–11 yr.

DISCUSSION

Comparison of objective and subjective measures of physical activity. The NHANES 2003–2004 accelerometer data are the first objective measurements of physical activity in a nationally representative health survey. These objective data are qualitatively consistent with findings based on self-report for age and gender. Males are generally more active than females, and physical activity is lower in successive age groups. However, the absolute count, duration, and adherence prevalence results from the accelerometer data provide a new and sobering picture of physical activity in the U.S. population. Although these are cross-sectional data, it seems from the count and duration outcomes that physical activity declines dramatically during adolescence; by ages 16–19 yr, mean levels of moderate activity are low, and vigorous activity is almost nonexistent. The low levels of activity are particularly evident when bouts of activity are considered.

Even with inclusion of every minute above the assigned threshold, by age 16 yr mean duration of vigorous activity is 3 min or less per day. Children (ages 6–11 yr) fare slightly better, obtaining 16 and 10 $\text{min}\cdot\text{d}^{-1}$ of vigorous activity for boys and girls, respectively. If moderate and vigorous activities are combined, the values change, but the patterns are similar. Children engaged in more than 1 $\text{h}\cdot\text{d}^{-1}$ of at least moderate-intensity physical activity as measured by accelerometer. By ages 12–15 yr, the mean time in moderate- or greater-intensity physical activity had dropped to between a third and a half of the value among those ages 6–11 yr, and it had dropped further among those ages 16–19 yr. When duration in bouts of at least 8–10 min is considered, as appropriate for older adolescents and adults, mean duration among those ages 16–19 yr is generally 10 $\text{min}\cdot\text{d}^{-1}$ or less for both genders. This value is considerably less than the 30 $\text{min}\cdot\text{d}^{-1}$ recommended for health promotion (17,31).

Compliance with the current physical activity recommendation. Forty-two percent of children met the recommendation to accumulate at least an hour of physical activity on most days of the week. Activity levels for other age groups were considerably lower, with the most dramatic difference occurring among adolescents. Adherence prevalence dropped from 49 to 12% for boys and from 35 to 3% for girls when comparing children ages 6–11 with those aged 12–15 and including every minute of activity above the moderate threshold. When activity in bouts of 8–10 min or longer was considered, adherence prevalence estimates were less than 5% among adults.

These prevalence estimates contrast with adherence estimates based on self-report from national surveys (26) that indicate that 25–33% of the population meets recommended physical activity levels. Estimates based on the 2001 and 2003 BRFSS that incorporate activity from household tasks in addition to leisure or recreation activities indicate that 45–46% of the population meets the recommended 30 min of moderate activity on five or more days per week (21). Self-report of physical activity in NHANES 2003–2004 that includes recreation, household, and transportation activity, led to an adherence prevalence estimate of approximately 51%, defined as an accumulation of 150 $\text{min}\cdot\text{wk}^{-1}$ of moderate or greater activity (data not shown).

These order-of-magnitude differences in adherence may be attributable to several factors. One possibility is that the accelerometer provides an estimate close to truth, and that respondents greatly overestimate their physical activity (9). The reporting overestimate could result from misclassifying sedentary or light activity as moderate, or from overestimates of activity duration. Misclassification of activity intensity may be related to the application of MET cutoffs to both objective and self-report data. Whereas researchers define cutoffs for accelerometers and assume that reported "moderate"-intensity activity is defined as 3.0–6.0 METs, respondents to questions are unlikely to be familiar with the MET metric. Respondents may apply relative intensity definitions in answering questions, despite attempts to calibrate the responses by providing example activities and physiologic cues. Alternatively, the self-reported activity may be accurate, and the difference is attributable to certain types of activity, such as bicycling or swimming, not being captured by accelerometers (33). However, according to the reports in NHANES 2003–2004, fewer than 10% of adult respondents reported any bicycling for leisure, and fewer than 5% reported swimming. It should also be noted that the accelerometer is capturing activity in all contexts, including activities that are not covered by the questionnaire, such as occupation.

Inclusion of occupational and transportation activity in the objective measure may explain why Mexican American adults had the highest levels of physical activity, according to counts per minute or duration of moderate- or greater-intensity activity counting every minute. Data from self-report surveys that focus primarily on leisure-time activity find that the Hispanic population has the lowest level of activity among racial/ethnic groups (30). The accelerometer

may be detecting differences in occupational and transportation physical activity, which are not typically included in surveys. Inclusion of questions about transportation activity in surveys decreases disparities in levels of physical activity among racial/ethnic groups (3).

Limitations. The NHANES physical activity monitor data are among the first objective measures of physical activity in a national survey, but they are not a panacea for physical activity assessment. The use of a single, waist-mounted, uniaxial accelerometer, with cut points based on walking, misses some physical activity that involves upper-body movement or the additional energy cost of load carrying. However, walking is the most prevalent form of leisure-time physical activity in the United States (24), and it also occurs in occupational and transportation activity.

The cut-point values chosen for moderate and vigorous activity are based on limited data. Use of a single cut point for all adults may lead to an underestimate of moderate-intensity activity for older adults by not accounting for the decline in exercise capacity with age. The moderate and vigorous cut points for children and adolescents (ages 6–17 yr) were selected to correspond to 4 and 7 METs, rather than the usual adult values of 3 and 6 METs. These values account for the higher contribution of resting energy expenditure to the total expenditure of youth (11,19). The accelerometer-count threshold that distinguished brisk walking from slow walking, determined by Treuth et al. (25) for girls ages 13–14 yr, was closely approximated by the selected values for moderate intensity for these ages, suggesting that the 4-MET cut point was appropriate. Although the choice of cut point will affect duration of moderate- or greater-intensity activity, the patterns of results obtained with application of cut points did not vary dramatically from those based on counts per minute. A graphic examination of the effect of cut-point choice on adherence prevalence for adults found that adherence varied little and was less than 10% for any cut point greater than 1200 counts per minute. For values less than 1000 counts per minute, small differences in cut-point value were associated with large changes in the prevalence of adherence.

It is important to recognize that the current recommendation to accumulate 30 min of physical activity on most days (17,31) is based on epidemiological associations between self-reported physical activity and health outcomes. Epidemiological relationships based on objective measures might result in different recommendations for physical activity levels. Less than 30 $min \cdot d^{-1}$ of physical activity as measured by an accelerometer may provide significant health benefits, because lower levels of objectively measured physical activity correspond to higher levels of self-reported physical activity.

Great care must be taken when interpreting self-reported physical activity in clinical practice, public health program design and evaluation, and epidemiological research. Bias in self-reports could lead to erroneous conclusions in intervention and epidemiological trials. This bias could also make it difficult to determine whether patients are compliant with therapeutic recommendations concerning health behavior in clinical settings. Increased use of accelerometers or other objective measures may help ameliorate some of these challenges.

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