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Original Contribution

Ten-Year Changes in Accelerometer-Based Physical Activity and Sedentary Time During Midlife

The CARDIA Study

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We describe 10-year changes in accelerometer-determined physical activity (PA) and sedentary time in a midlife cohort of the Coronary Artery Risk Development in Young Adults Study, within and by race and sex groups. Participants (n = 962) wore the accelerometer with valid wear (≥4 of 7 days, ≥10 hours per day) at baseline (2005–2006; ages 38–50 years) and 10-year follow-up (2015–2016; ages 48–60 years). Data were calibrated to account for accelerometer model differences. Participants (mean age = 45.0 (standard deviation, 3.5) years at baseline) had reduced accelerometer counts overall (mean = −65.5 (standard error (SE), 10.2) counts per minute/day), and within race and sex groups (all $P < 0.001$). Sedentary time increased overall (mean = 37.9 (SE, 3.7) minutes/day) and within race and sex groups, whereas light-intensity PA (mean = −30.6 (SE, 2.7) minutes/day) and moderate- to vigorous-intensity PA (mean = −7.5 (SE, 0.8) minutes/day) declined overall and within race and sex groups (all $P < 0.001$). Significant differences in 10-year change estimates were noted by race and sex groups for accelerometer counts, sedentary time, and moderate- to vigorous-intensity PA bouts; black men had the greatest reductions in PA compared with other groups. PA declines during midlife were characterized by reductions in light-intensity PA with increases in sedentary time, which may have important health consequences. Targeted efforts are needed to preserve PA, regardless of intensity level, across midlife.

accelerometry; cohort study; diverse sample

Abbreviations: CARDIA, Coronary Artery Risk Development in Young Adults; MVPA, moderate- to vigorous-intensity physical activity; PAG, physical activity guidelines; SE, standard error.

A key strategy to attenuate the public health burden attributable to noncommunicable diseases and mobility disability is the promotion of lifestyle behaviors, including physical activity. There is substantial evidence to suggest achieving the US Department of Health and Human Services' physical activity guidelines (PAG) (1) of at least 150 minutes per week of moderate-intensity physical activity, at least 75 minutes per week of vigorous-intensity physical activity, or an equivalent combination of moderate- and vigorous-intensity physical activity (MVPA) reduces risk of premature death and several leading causes of disease and disability. Physical activity is also recommended for management of related conditions, including obesity, hypertension, and type 2 diabetes (1–3). Prolonged sedentary time also is discouraged in the PAG (1).

Age-related declines in MVPA, based primarily on reported methods (e.g., questionnaires), are well documented in the literature (1, 4), including the Coronary Artery Risk Development in Young Adults (CARDIA) study (5–9). Furthermore, these age-related declines are likely due to physiological changes, including reductions in aerobic and muscular fitness (10, 11). However, due to previous reliance on questionnaires, there is currently limited evidence demonstrating total physical activity change and change within intensity categories with aging. This important gap in knowledge was recently highlighted in the *2018 Physical Activity Guidelines Advisory Committee Scientific Report* (3).

CARDIA is uniquely poised to contribute to these research gaps because accelerometer-based measures were implemented in this biracial cohort early (2005–2006) in comparison with other US-based cardiovascular observational cohort studies. Furthermore, CARDIA data include a second wave of accelerometer data collected 10 years later, which provide the opportunity to describe changes in accelerometer-based measures across 10 years during midlife. Midlife may be a particularly vulnerable time during adulthood because it corresponds to a period when risk of disease and disability escalates (12). Yet, compared with older adulthood, midlife may be a time when individuals are more willing and physically able to initiate a physical activity routine, particularly after retirement when there are more discretionary hours during which to be active (13). Therefore, the primary purpose of this study was to describe the 10-year changes in accelerometer-based physical activity and sedentary behavior measures of CARDIA participants and explore differences within and across black men and women and white men and women. A secondary objective was to describe these 10-year changes by baseline age and cardiorespiratory fitness level.

METHODS

Beginning in 1985–1986, CARDIA researchers recruited 5,115 participants aged 18–30 years from 4 geographical locations (Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California). Baseline data for this analysis were collected at examinations in year 20 (2005–2006) and at follow-up in year 30 (2015–2016), at which times retention among survivors was 72% and 71%, respectively. At both visits, accelerometer data were collected as part of ancillary studies performed in conjunction with the core clinical examination. Standardized questionnaires were used at each visit to assess participant characteristics, including sex, race, age, and educational attainment. Reported physical activity was assessed at all visits using the CARDIA Physical Activity History, a reliable and valid measure (14, 15). At baseline, a maximal symptom-limited, graded exercise test, using a modified Balke protocol (16), was completed to assess cardiorespiratory fitness. Participants provided written informed consent, and CARDIA is approved annually by the institutional review boards of each participating center.

Accelerometer data were collected using the ActiGraph 7164 and wGT3X-BT accelerometer models (ActiGraph, Pensacola, Florida) at the baseline and follow-up examinations, respectively, using identical protocols. Participants were asked to wear the accelerometer on their hip for 7 consecutive days during all waking hours (except during water-based activities). Once returned, data were downloaded and screened for wear time using the Troiano algorithm (17).

These analyses included 962 participants (37.6% black women; 63.2% women overall) with valid wear time (17) (≥10 hours per day for ≥4 days) at both visits. The analytic sample was statistically significantly older (mean age = 25.1 (standard error (SE), 0.11) vs. 24.8 (SE, 0.06) years at year 0) and more likely to be female (63.2% vs. 52.5%), white (62.5% vs. 45.2%), and hold a Bachelor's degree (40.3% vs. 33.4%) (all $P < 0.001$); no significant difference in reported physical activity level was observed.

To optimize consistency across visits, raw data from the vertical axis of the wGT3X-BT accelerometer model were reintegrated to 60-second epochs with the low-frequency extension applied (18). Based on results of a CARDIA methodological substudy ($n = 87$), follow-up accelerometer count data were calibrated (counts divided by 1.088) to account for ActiGraph model differences as reported by Whitaker et al. (19). Total counts per minute and average counts per minute/day were calculated and minutes per day spent performing sedentary activity (i.e., <100 counts per minute), light-intensity physical activity (i.e., 100–1,951 counts per minute), and MVPA (i.e., ≥1,952 counts per minute) were estimated using Freedson cutpoints (20). Freedson cutpoints were selected because of their broad use in physical activity research. MVPA (calculated as every minute ≥1,952 counts per minute) and MVPA bouts (estimates only include ≥8 of 10 consecutive minutes of ≥1,952 counts per minute) (17) are reported. Although there is some controversy about using accelerometer-based data to assess behavioral targets (21, 22), at least 150 minutes/week of accumulated MVPA was used to classify participants as meeting PAG.

Ten-year change estimates were computed as follow-up minus baseline data. Absolute change, rather than percent change, is reported to optimize the interpretations of the findings (i.e., minutes/day vs. percent change). Accelerometer estimates are reported as means with standard errors or proportions. Student *t* test was used to examine differences in baseline and follow-up accelerometer estimates, and overall and within race and sex groups. Analysis of variance and Tukey post hoc tests were used to examine differences in the 10-year change estimates between race and sex groups. To address the secondary study objective, differences in accelerometer estimates were also examined by baseline (i.e., year 20) age (<45 years vs. ≥45 years) and fitness level (less than vs. more than the median value of 452 seconds); Student *t* test was used to examine differences in the 10-year change estimates by the age and fitness categories. All statistical significance tests were 2-sided with the type I error level set at $P < 0.05$. All analyses were generated with SAS/STAT software, version 9.4 (SAS Institute, Inc., Cary, North Carolina).

RESULTS

Table 1 lists descriptive accelerometer data among the full analytic sample (mean age = 45.0 (standard deviation, 3.5) years at baseline). There was excellent participant compliance with wear time, at approximately 15 hours/day at each visit. Therefore, 10-year change estimates were not further adjusted for wear time. Total (counts per day) and average accelerometer counts (count per minute/day), composite measures reflecting both sedentary and physical activity (23), significantly decreased over 10 years, and included increases in sedentary time (mean = 37.9 (SE, 3.7) minutes/day), coupled with reductions in light-intensity physical activity (mean = −30.6 (SE, 2.7) minutes/day) and MVPA (mean = −7.5 (SE, 0.8) minutes/day). A slight increase in MVPA bouts (mean = 2.3 (SE, 0.7) minutes/day) was also observed.

There were also no significant differences in accelerometer wear time at baseline and follow-up within or between race and sex groups (all $P > 0.05$); therefore, estimates were

Table 1. Baseline (2005–2006), 10-Year Follow-up (2015–2016), and 10-Year Change in Accelerometer-Determined Physical Activity and Sedentary Behavior Estimates ($n = 962$), Coronary Artery Risk Development in Young Adults Study

Variable	Baseline, Mean (SE)	Follow-up, Mean (SE)	10-Year Change, Mean (SE)	*P* Value[a]
Wear time, minutes/day	894.1 (2.8)	893.9 (2.9)	−0.17 (3.3)	0.96
Total accelerometer counts, per 10,000 counts per day	35.1 (1.2)	28.7 (0.4)	−6.3 (1.2)	<0.001
Average accelerometer counts, counts per minute/day	386.2 (10.2)	320.7 (4.2)	−65.5 (10.2)	<0.001
Sedentary time, minutes/day	495.4 (3.3)	533.2 (3.4)	37.9 (3.7)	<0.001
Light-intensity PA, minutes/day	362.1 (2.7)	331.5 (2.7)	−30.6 (2.7)	<0.001
MVPA, minutes/day	36.6 (0.8)	29.2 (0.8)	−7.5 (0.8)	<0.001
MVPA in bouts, minutes/day[b]	12.5 (0.6)	14.8 (0.6)	2.3 (0.7)	<0.001
Reported physical activity[c], EU	353.3 (9.1)	340.3 (8.7)	−13.0 (7.5)	0.09

Abbreviations: EU, exercise units; MVPA, moderate- to vigorous-intensity physical activity; PA, physical activity; SE, standard error.
[a] Differences between baseline and follow-up values were determined using a Student *t* test.
[b] At least 8 of 10 consecutive minutes above the threshold of 1,952 counts per minute.
[c] $n = 956$.

also left unadjusted (Table 2). In general, 10-year change patterns in the analytic sample emerged within each race and sex group. However, 10-year increases in MVPA bouts were significant only in white men and white women (mean = 4.7 (SE, 1.3) minutes/day and 2.7 (SE, 0.9) minutes/day, respectively; both $P < 0.01$). Significant differences in 10-year changes in accelerometer counts, sedentary time, and MVPA bouts were noted by race and sex groups (all $P < 0.05$). Black men, who started with the highest accelerometer counts, had the largest reductions (mean = −181.0 (SE, 77.0) counts per minute per day)—a reduction that was significantly different from all other sex and race groups. Compared with white women, black women, who started with the lowest counts, had significantly greater reductions (all $P < 0.05$). Ten-year changes in sedentary time and MVPA bouts also significantly differed between black men and white men (both $P < 0.05$). Black men also had the greatest declines in reported physical activity compared with all other race and sex groups. Finally, the proportion of participants meeting PAG was higher at baseline than at follow-up, regardless of race or sex group (Web Figure 1, available at https://academic.oup.com/aje). As shown in Web Table 1, younger participants at baseline had significantly larger increases in sedentary time compared with that of the older age group. Participants with higher cardiorespiratory fitness level at baseline had significantly larger increases in MVPA bouts ($P = 0.003$). No other differences in the 10-year accelerometer change estimates were noted by baseline age or fitness groups.

DISCUSSION

Over 10 years, CARDIA participants experienced significant reductions in total and average accelerometer count estimates. The declines were primarily reflected as reductions in light-intensity physical activity (mean = 30.6 minutes/day) and approximately reciprocal increases in sedentary time (mean = 37.9 minutes/day). Minimal, yet significant, reductions in MVPA were also noted that support previous findings based on questionnaire responses ($P < 0.001$) (5–9). Significant differences in accelerometer counts, sedentary time, and MVPA in bouts were also noted over 10 years by race and sex groups (all $P < 0.05$), with black men having the greatest declines in average accelerometer counts compared with all other groups ($P < 0.05$). Differences in 10-year changes in accelerometer-determined physical activity and sedentary behavior were also noted by baseline (i.e., year 20 follow-up) age and cardiorespiratory fitness categories.

The observed reductions in light-intensity physical activity across midlife are concerning, particularly within the context of increases in sedentary time (24). Although this evidence is still emerging (3), partly because of the increased capabilities and feasibility of implementing accelerometer-based measures in population-based research (23), the potential age-related health benefits of light-intensity physical activity have been demonstrated in studies conducted in older adults. More specifically, Buman et al. (25) found that replacing 30 minutes/day of sedentary time with light-intensity physical activity was associated with better reported physical health. Similarly, in older women, LaMonte et al. (26) found that greater amounts of light-intensity physical activity were associated with improvements in several cardiovascular risk factors (e.g., adiposity measures, triglyceride levels) and 10-year cardiovascular disease risk score. A significant inverse association of light-intensity physical activity with mortality risk was also found in prospective studies of older women (27) and men (28). This preliminary, supportive evidence leads to the overarching recommendation by the 2018 Physical Activity Guidelines Advisory Committee for additional research examining the role and contribution of light-intensity physical activity, alone or in combination with MVPA, relative to health outcomes (3). Given current study findings, the health consequences of age-related transitions from time spent in light-intensity physical activity to sedentary pursuits should also be considered. Regardless, as this evidence accumulates, future iterations of the PAG should consider sedentary and light-intensity physical activity targets, in addition to MVPA, for overall health benefit.

Results of stratified analyses suggest important findings among CARDIA's black participants. Although black men were the most active at baseline, black men subsequently had the greatest declines in accelerometer counts compared with all race and sex groups over 10 years. Conversely, the 10-year change profile among black women suggested consistently low levels of

Table 2. Baseline (2005–2006), 10-Year Follow-up (2015–2016), and 10-Year Change in Accelerometer-Determined Physical Activity and Sedentary Behavior Estimates Within and Stratified by Race and Sex Groups (n = 962), Coronary Artery Risk Development in Young Adults Study

Variable	Black Men (n = 117; 12.2%), mean (SE)			White Men (n = 237; 24.6%), mean (SE)			Black Women (n = 244; 25.4%), mean (SE)			White Women (n = 364, 37.8%), mean (SE)			P Value[a]
	BL	Follow-up	10-Year Change	BL	Follow-up	10-Year Change	BL	Follow-up	10-Year Change	BL	Follow-up	10-Year Change	
Wear time, minutes/day	906.3 (9.8)	909.9 (10.8)	3.7 (13.4)	905.1 (4.7)	902.3 (5.5)	−2.8 (5.8)	880.1 (6.4)	889.2 (6.2)	9.1 (7.5)	892.4 (4.2)	886.5 (4.0)	−5.8 (4.5)	0.34
Total accelerometer counts, per 10,000 counts per day	50.2 (9.7)	29.9 (1.2)	−20.4 (9.7)[b]	36.4 (0.9)	32.2 (0.9)	−4.3 (0.8)[c]	28.9 (0.7)	25.0 (0.7)	−3.9 (0.7)[c]	33.3 (0.6)	28.6 (0.6)	−4.7 (0.6)[c]	0.001[d,e,f]
Average accelerometer counts, counts per minute/day	509.4 (76.5)	328.5 (13.8)	−181.0 (77.0)[b]	402.6 (9.2)	355.5 (9.5)	−47.0 (8.6)[c]	329.8 (7.9)	282.5 (7.5)	−47.2 (7.7)[c]	373.8 (6.4)	321.2 (6.1)	−52.6 (6.5)[c]	0.004[d,e,f,g]
Sedentary time, minutes/day	488.2 (11.2)	548.8 (11.8)	60.6 (13.7)[c]	520.5 (6.2)	545.2 (6.7)	24.6 (6.8)[c]	484.0 (6.9)	526.7 (7.4)	42.7 (7.6)[c]	488.9 (4.9)	524.8 (4.4)	35.9 (5.3)[c]	0.04[d]
Light intensity PA, minutes/day	371.5 (9.6)	327.5 (8.2)	−44.0 (9.3)[c]	339.8 (5.2)	319.3 (5.6)	−20.4 (4.9)[c]	370.4 (4.9)	343.0 (5.3)	−27.4 (5.8)[c]	368.0 (4.2)	333.0 (4.3)	−35.0 (4.2)[c]	0.054
MVPA, minutes/day	46.6 (3.8)	33.6 (2.6)	−13.0 (3.8)[c]	44.8 (1.7)	37.7 (1.8)	−7.1 (1.5)[c]	25.7 (1.2)	19.5 (1.2)	−6.2 (1.3)[c]	35.5 (1.1)	28.7 (1.1)	−6.8 (1.2)[c]	0.09
MVPA in bouts, minutes/day[h]	15.9 (2.8)	14.3 (2.0)	−1.6 (3.0)	14.6 (1.2)	19.3 (1.4)	4.7 (1.3)[c]	7.3 (0.8)	8.5 (1.0)	1.1 (0.9)	13.4 (0.8)	16.1 (1.0)	2.7 (0.9)[i]	0.04[f]
Reported physical activity[i], EU	483.2 (37.9)	392.9 (32.0)	−90.4 (31.7)[j]	423.7 (17.2)	433.6 (18.4)	9.9 (15.2)	242.9 (14.8)	229.2 (14.3)	−13.7 (13.4)	340.0 (12.8)	336.9 (14.4)	−3.2 (10.6)	0.001[d,e,f]

Abbreviations: BL, baseline; EU, exercise units; MVPA, moderate- to vigorous-intensity physical activity; PA, physical activity; SE, standard error.

[a] For differences by race and sex groups based on analysis of variance.

[b] $P < 0.05$.

[c] $P < 0.001$.

[d] Black men different than white men.

[e] Black men different than black women.

[f] Black men different than white women.

[g] Black women different than white women (d through g based on Tukey studentized range (honestly significant difference) test for differences.

[h] At least 8 of 10 consecutive minutes above the 1,952 counts per minute threshold.

[i] $n = 956$.

[j] $P < 0.01$.

physical activity over time. This provides an opportunity to evaluate potential differences in subsequent health risk of individuals decreasing versus those with consistently low levels of physical activity over time. The magnitude of 10-year increases in sedentary time among blacks versus whites is also concerning, given emerging evidence supporting the associated health consequences (24). These specific physical activity behavioral-change profiles may contribute to the observed disparity in diabetes incidence (29) and cardiovascular disease–related death among blacks (30).

Strengths of this study include a large biracial sample of men and women with repeated measures of accelerometry that span midlife. A limitation could be that due to continually emerging technology, different ActiGraph models were used. However, after calibration, measures were comparable for all summary estimates (19). Other limitations include possible misclassification of sedentary and light-intensity activity due to placement of the accelerometer at the hip, limited (or no) detection of certain activity types (e.g., bicycling, swimming), smaller sample size within some race or sex group strata, and no interim data collection time point. Finally, the participants represent a select sample, which limits generalizability to CARDIA and the broader US population.

In summary, study findings complement those of previous studies documenting age-related decline in physical activity. Yet, our findings provide novel contextual information illustrating patterns of sedentary time and physical activity change by intensity category. To support intervention research, studies are needed to evaluate potential health consequences of age-related physical activity changes while also examining the social and health-related factors that contribute to these declines.

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