Sustained and Shorter Bouts of Physical Activity Are Related to Cardiovascular Health

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ABSTRACT

GLAZER, N. L., A. LYASS, D. W. ESLIGER, S. J. BLEASE, P. S. FREEDSON, J. M. MASSARO, J. M. MURABITO, and R. S. VASAN. Sustained and Shorter Bouts of Physical Activity Are Related to Cardiovascular Health. *Med. Sci. Sports Exerc.*, Vol. 45, No. 1, pp. 109–115, 2013. **Purpose**: Whereas greater physical activity (PA) is known to prevent cardiovascular disease (CVD), the relative importance of performing PA in sustained bouts of activity versus shorter bouts of activity on CVD risk is not known. The objective of this study was to investigate the relationship between moderate-to-vigorous PA (MVPA), measured in bouts ≥10 and <10 min, and CVD risk factors in a well-characterized community-based sample of white adults. **Methods**: We conducted a cross-sectional analysis of 2109 participants in the Third Generation Cohort of the Framingham Heart Study (mean age = 47 yr, 55% women) who underwent objective assessment of PA by accelerometry over 5–7 d. Total MVPA, MVPA done in bouts ≥10 min ($MVPA_{10+}$), and MVPA done in bouts <10 min ($MVPA_{<10}$) were calculated. MVPA exposures were related to individual CVD risk factors, including measures of adiposity and blood lipid and glucose levels, using linear and logistic regression. **Results**: Total MVPA was significantly associated with higher HDL levels and with lower triglycerides, BMI, waist circumference, and Framingham risk score ($P < 0.0001$). $MVPA_{<10}$ showed similar statistically significant associations with these CVD risk factors ($P < 0.001$). Compliance with national guidelines (≥150 min of total MVPA) was significantly related to lower BMI, triglycerides, Framingham risk score, waist circumference, higher HDL, and a lower prevalence of obesity and impaired fasting glucose ($P < 0.001$ for all). **Conclusions**: Our cross-sectional observations on a large middle-age community-based sample confirm a positive association of MVPA with a healthier CVD risk factor profile and indicate that accruing PA in bouts <10 min may favorably influence cardiometabolic risk. Additional investigations are warranted to confirm our findings. **Key Words:** ACCELEROMETER, HEART DISEASE, EXERCISE, GUIDELINES

Lack of physical activity (PA) has been consistently and directly related to the development of cardiovascular disease (CVD) risk factors such as obesity, hypertension, dyslipidemia, and glucose intolerance (26,27,38). Conversely, PA reduces the risk of CVD events, functional disability, cognitive decline, and all-cause mortality (1,9, 10,19,20,29,40).

Prior studies of PA and health outcomes have been constrained by a lack of objective assessment of activity and a focus on leisure time PA. Accelerometers substantially improve the accuracy, reliability, and comprehensive profiling of PA by measuring both movement and its intensity during each daily minute, thereby quantifying the frequency, duration, and total volume of PA. However, there are limited data regarding the association of PA assessed by accelerometry (including compliance with current national PA guidelines) with the CVD risk factor profile in the community. In addition, whereas PA is known to play a significant role in the prevention of CVD, the relative importance of accumulating activity in sustained versus shorter bouts of time requires further investigation. A comprehensive review concluded that there are insufficient data comparing the effects of short versus longer bouts of PA, independent of activity intensity and amount (24). In interventional studies comparing single long bouts of exercise with multiple short exercise bouts, there is relatively strong evidence that comparable cardiorespiratory fitness may be achieved with different fractionation of total PA volume (27). There is conflicting evidence as to whether continuous PA exposure has a more favorable effect on CVD risk factors, and a reliable estimate of the effect of fractionated exercise on CVD risk factors is lacking. National guidelines indicate that PA should be accrued

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in bouts of at least 10 min for potential health benefits (25,27), yet the guidelines also state that more research is needed to determine the health benefits of PA done in bouts <10 min (13). In this context, accelerometry offers the opportunity to evaluate the effect of PA accrued in bouts ≥10 min versus bouts <10 min, independent of activity intensity and amount (24).

In the present investigation, we assessed the clinical correlates of moderate-to-vigorous PA (MVPA), measured in total minutes of MVPA, MVPA accumulated in bouts ≥10 min ($MVPA_{10+}$), and MVPA accumulated in bouts <10 min, as measured by accelerometry in the Third Generation Cohort of the Framingham Heart Study (FHS), a well-characterized community-based cohort study of white US adults.

METHODS

The FHS is a longitudinal community-based cohort that was initiated in 1948 to prospectively identify risk factors for CVD (6). Recruitment of the Third Generation (children of the Offspring cohort (28) and grandchildren of the original FHS cohort) occurred between 2002 and 2005 (examination 1) (33). For the present investigation, our study sample was derived from the Third Generation cohort participants who attended the second examination (May 2008 to October 2010), when accelerometry was routinely performed.

At each FHS examination, participants undergo a routine medical history and physical examination including measurement of resting blood pressure, anthropometry, and laboratory evaluation of standard CVD risk factors (18). Data on education, employment status, current smoking, and levels of self-reported general health are also obtained. Hypertension was defined as a BP ≥140/90 mm Hg or current use of antihypertensive medication; diabetes mellitus (DM) was defined by a fasting glucose ≥126 $mg \cdot dL^{-1}$ or use of antidiabetic medications; impaired glucose tolerance (IGT) as a fasting glucose 100 to <126 $mg \cdot dL^{-1}$. Overweight was defined as body mass index (BMI) ≥25 $kg \cdot m^{-2}$, and obesity was defined as BMI ≥ 30 $kg \cdot m^{-2}$. Prevalent CVD includes CHD (angina and acute coronary syndrome, including myocardial Infarction), cerebrovascular disease (stroke and transient ischemic attack), intermittent claudication, and heart failure. The 10-yr Framingham risk score was computed using gender-specific equations (39).

PA was monitored by an omnidirectional accelerometer (Actical Model No. 198-0200-00; Philips Respironics, Bend, OR). It records accelerations in the range of 0.05*g*–2.0*g* and is sensitive to movements in the range of 0.5–3.0 Hz. The Actical has an internal time clock and a 64 kB memory and measures the magnitude of acceleration and deceleration associated with body movements at a sampling rate of 32 Hz. The recorded signals are scored as "counts" summed over a user-defined epoch (30 s). At their routine FHS clinic examination, participants were asked to wear the Actical on a waist-worn belt for 24 $h \cdot d^{-1}$ for 8 d (to achieve full seven "wear" days) and to take the device off only when showering. Participants returned the activity monitor to the FHS by mail. FHS clinic staff downloaded the data and visually screened the raw accelerometer files for spurious data. Checks for spurious data include the following: 1) comparing the count maxima, 2) relating count maxima with device serial number to rule out "batch" effects, and 3) comparing count plateau conditions. Data were processed in-house using custom KineSoft software (KineSoft, Saskatchewan, Canada) (8), and quality control screening was regularly performed. Accelerometer data files were used if they had at least five of seven "valid" wear days with at least one of the valid days being a weekend day (7); >10 h of wear time were required for a "valid day" (36).

Of the 3101 individuals attending the second examination cycle during May 2008 to October 2010, 2616 had accelerometry data available passing initial QC checks. Participants were excluded from the present investigation if they did not wear the accelerometer for at least five valid days with at least one weekend day (n = 407), had prevalent cardiovascular disease (n = 49), were missing one or more covariates (n = 48), or had a self-reported health classified as poor (n = 3). After these exclusions, 2109 participants were eligible for the present analyses. The study protocol was approved by the Boston University Medical Center Institutional Review Board, and all attendees provided written informed consent.

Time spent in MVPA is based on the application of count thresholds obtained from calibration studies that relate accelerometer counts to measured activity energy expenditure. Intensity thresholds were calculated similar to the methods of Troiano et al. (36); that is we used a weighted average of the available ambulatory-only regression equations from two published studies by Heil (17) and Crouter and Bassett (5). The resulting cut point criteria were 1486–5558 counts per minute for moderate intensity and ≥5559 counts for vigorous intensity, corresponding to MET values of 3–6 for moderate-intensity and >6 for vigorous-intensity activities. Total PA time at each intensity level is the sum of the minutes at a given intensity while the accelerometer is worn. $MVPA_{10+}$ is calculated as the sum of moderate and vigorous activity accumulated in bouts of at least 10 min allowing for a 1- to 2-min interruption. $MVPA_{<10}$ was calculated as the sum of moderate- and vigorous-intensity activities accumulated <10 min at a time. The US Physical Activity Guidelines for Americans recommend that adults get 150 min of MVPA per week, with the activity being accumulated in bouts of at least 10 min (http://www.health.gov/paguidelines/). We defined compliance with PA guidelines in two ways: ≥150 min of MVPA done in bouts of ≥10 min ($MVPA_{10+}$) and ≥150 total MVPA regardless of bout duration.

We used means and SD to describe the distributions of MVPA by sex, season, education, employment status, current smoking, and levels of self-reported general health (fair, good, very good, and excellent). Generalized linear and logistic regression models were used to examine the

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cross-sectional association of MVPA with CVD risk factors. Sensitivity analyses using general estimating equations to account for familial correlations were also performed (21). Total MVPA, $MVPA_{10+}$, and MVPA <10 min were related to anthropometric measures (BMI, waist circumference), fasting glucose, triglycerides, HDL cholesterol, systolic and diastolic BP, and the Framingham risk score. The binary clinical outcomes of hypertension, obesity, IGT, and DM were also evaluated using logistic regression models. All models were adjusted for the following covariates: age, sex, education level, self-reported general health and accelerometer "wear time." Analyses of $MVPA_{10+}$ and $MVPA_{<10}$ were adjusted for each other to assess their independent effects. Other potential confounders, such as smoking, season, and employment status, were evaluated and not included in the final models because they did not materially influence the results. We used the *F*-statistic to test whether there was a difference in the strength of associations between betas from the $MVPA_{10+}$ models and those from the $MVPA_{<10}$ models. We assessed effect modification of BMI category by modeling appropriate interaction terms in the statistical models. To assess the association of compliance with PA guidelines on CVD risk factors, we estimated separate regression models relating each definition of compliance to CVD risk factors above (adjusting for covariates listed above). To account for multiple testing, statistical significance was set at $P < 0.001$ (Bonferroni correction for 12 CVD risk factors and 3 exposure variables, 0.0014 = 0.05/36). Analyses were performed using SAS version 9.2 (SAS Institute, Cary, NC) and StataSE version 11.2 (StataCorp, College Station, TX) software.

RESULTS

Table 1 presents the characteristics of the study sample (mean age = 47 yr, 55% women), by sex, at the time of their FHS examination. More than half of the population was overweight, and the majority of participants (74%) reported that they were in very good or excellent health. Although 600 min of wear time was required for a "valid day," the average daily "wear time" of the accelerometer was much greater, at 926 ± 96 min; 69% of participants wore the accelerometer for seven valid days. On average, participants engaged in 28 ± 21 $min{\cdot}d^{-1}$ of MVPA, of which approximately 9 ± 13 min was $MVPA_{10+}$ and 19 ± 14 min was $MVPA_{<10}$. The partial correlation between sustained MVPA ($MVPA_{10+}$) and shorter bouts was 0.25 ($P < 0.0001$), after adjustment for age and sex. Ten percent of men and 15% of women met the strict PA guidelines of performing ≥150 $min{\cdot}wk^{-1}$ of $MVPA_{10+}$; 56% of men and 47% of women were compliant when considering total MVPA (Table 1). PA levels were higher in warmer months, among nonsmokers, those with higher education levels, and better self-reported health (Table 2).

Total MVPA was significantly associated with lower circulating triglycerides, BMI, waist circumference, overall Framingham risk score, and higher HDL concentrations (Table 3, $P < 0.0001$ for all). Total MVPA was also related to a lower prevalence of obesity. An increase of 10 $min{\cdot}d^{-1}$ of MVPA was associated with 15% lower obesity prevalence (odds ratio per 10 $min{\cdot}d^{-1}$ MVPA = 0.85, 95% confidence interval = 0.80–0.90). Shorter bouts of MVPA ($MVPA_{<10}$) showed a similar pattern of statistically significant relations with these CVD risk factors, independent of $MVPA_{10+}$ (Table 3). Both shorter bouts of MVPA and $MVPA_{10+}$ were associated with lower triglycerides, waist circumference, BMI, and higher HDL. $MVPA_{<10}$ was also significantly related to lower Framingham risk score. There was no difference in the strength of associations when comparing the betas from $MVPA_{10+}$ models to those from the $MVPA_{<10}$ models (Table 3). None of the MVPA measures were associated with blood pressure, fasting blood glucose level, DM prevalence, or impaired fasting glucose. In sensitivity analyses, we examined the effect of additional adjustment for BMI, which may act as both a confounder and a mediator in the relationship between PA and CVD risk factors. Inclusion of BMI in the models resulted in slight attenuation of β coefficients but remained highly statistically significant for most risk factors (see Table, Relations of MVPA measures to risk factors adjusted for BMI, Supplemental Digital Content 1, http://links.lww.com/MSS/A183).

Using the strict PA guideline definition (≥150 min of $MVPA_{10+}$), compliance was significantly related to lower triglycerides, BMI, waist circumference, and higher HDL ($P < 0.001$ for all; Table 4). Similarly, when considering both bout and nonbout MVPA, guideline compliance (≥150 min of total MVPA) was also related to lower Framinghamrisk score and prevalence of obesity and IGT, in addition to the risk factors above ($P < 0.001$ for all; Table 4). Limiting analyses to those participants who wore the accelerometer for the full 7 d did not notably change the results.

We examined relations of MVPA to CVD risk factors by sex and BMI category (normal weight vs overweight or obese). Although the pattern of associations was similar between the sexes, β coefficients were generally stronger for women than men (see Table, Relations of MVPA to risk factors by sex, Supplemental Digital Content 2, http://links.lww.com/MSS/A183). When examining associations of MVPA levels by BMI category, there were no notable differences in risk estimates between the different BMI categories, with the exception of the relationship with waist circumference. The strength of the associations between MVPA measures and waist circumference was greater among those who were overweight or obese compared with those who had a normal BMI.

DISCUSSION

The present investigation examined the associations between MVPA, accumulated in both ≥10- and <10-min bouts, and CVD risk factors using objectively measured PA by accelerometry. Although PA guidelines recommend

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TABLE 1. Characteristics of the study sample (n = 2109) by sex.

	Men (n = 959)	Women (n = 1150)	All
Age (yr)	47 ± 8	47 ± 9	47 ± 9
White race (%)	99	99	99
BMI ($kg \cdot m^{-2}$)	28.9 ± 4.6	26.5 ± 5.8	27.6 ± 5.4
SBP (mm Hg)	120 ± 12	112 ± 14	116 ± 14
DBP (mm Hg)	77 ± 8	71 ± 9	74 ± 9
Total cholesterol ($mg \cdot dL^{-1}$)	187 ± 34	186 ± 33	187 ± 33
HDL ($mg \cdot dL^{-1}$)	51 ± 14	67 ± 17	60 ± 18
Triglycerides ($mg \cdot dL^{-1}$)	127 ± 81	92 ± 48	108 ± 67
Waist circumference (cm)	102 ± 13	91 ± 15	96 ± 15
Fasting glucose ($mg \cdot dL^{-1}$)	99 ± 17	92 ± 13	95 ± 15
CRP ($mg \cdot L^{-1}$)	2.2 ± 3.7	2.8 ± 4.4	2.5 ± 4.1
Framingham risk score (%)	8.2 ± 6.5	3.1 ± 2.9	3.1 ± 2.9
Hypertension (%)	26	16	21
Overweight (%)	81	52	65
Obese (%)	34	23	28
Impaired fasting glucose (%)	37	16	25
DM (%)	5	3	4
Current smoking (%)	13	11	12
Very good or excellent health (%)	71	76	74
Highest degree of education (%)			
≤High school degree	16	12	14
More than high school	63	67	65
Graduate degree	21	21	21
Employment status (%)			
Homemaker or full-time student	1	11	6
Unemployed/retired	7	7	7
Employed (full or part-time)	91	81	86
Unemployed/on-leave for disability or health reasons	1	1	1
Accelerometer wear time ($min \cdot d^{-1}$)	939 ± 103	915 ± 88	926 ± 96
Light PA ($min \cdot d^{-1}$)	143 ± 53	133 ± 47	137 ± 50
Moderate PA ($min \cdot d^{-1}$)	28 ± 20	24.2 ± 17.6	25 ± 18
Vigorous PA ($min \cdot d^{-1}$)	2 ± 5	3 ± 6	2 ± 6
MVPA total ($min \cdot d^{-1}$)	30 ± 22	26 ± 10	28 ± 21
$MVPA_{10+}$ ($min \cdot d^{-1}$)	7 ± 11	10 ± 14	9 ± 13
$MVPA_{<10}$ ($min \cdot d^{-1}$)	22.8 ± 16.3	16.3 ± 11.0	19 ± 14
PA guideline compliance (MVPA, %)	56	47	51
PA guideline compliance ($MVPA_{10+}$, %)	10	15	13

Values are mean ± SD or percentage as indicated.

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accumulating doses of MVPA in bouts of at least 10 min, in our community-based study of white adults in the United States, the majority of MVPA was accumulated in shorter bouts. Shorter bouts of MVPA were independently related to lower triglyceride levels, BMI and Framingham risk score, smaller waist circumference, and a lower prevalence of obesity, even after controlling for $MVPA_{10+}$. In addition, $MVPA_{<10}$ had similar magnitudes of association as $MVPA_{10+}$ associations. Approximately half of our middle-age adult population met the recommendation of at least 150 min of total MVPA per week, but only 12% engaged in this level of activity in bouts of ≥10 min. Compliance with national PA guidelines was associated with a statistically significant lower CVD risk factor burden and lower prevalence of obesity and IGT, regardless of how MVPA was accrued ($MVPA_{10+}$ or in nonbouts).

The amount of MVPA among our Framingham participants was similar to that of the National Health and Nutrition Examination Survey (NHANES) using accelerometry. Whereas NHANES used the ActiGraph accelerometer, limiting direct comparison, the 2005–2006 NHANES accelerometry sample (mean age = 47 yr, 50% male, 71% non-Hispanic white) engaged in 24.2 $min \cdot d^{-1}$ of total MVPA (3), and approximately 8%–10% (depending upon measurement approach) of their non-Hispanic white sample met the 2008 physical activity guidelines of 150 $min \cdot wk^{-1}$ of MVPA (37). Our FHS sample was slightly more active, engaging in approximately 28 $min \cdot d^{-1}$ of total MVPA and 12% meeting the 2008 physical activity guidelines for Americans. This could be due to accelerometer measurement differences, choice of intensity thresholds, or a reflection of a temporal trend in increasing PA levels among Americans because our study collected data from 2008 to 2011 and national surveys results suggest that activity levels may be increasing (4).

Our finding that objectively measured MVPA is cross-sectionally related to a lower CVD risk factor burden is consistent with published reports using NHANES accelerometry data. Sisson et al. (31) reported that accelerometer-derived steps per day were associated with lower prevalence of the metabolic syndrome, and adults who took more steps had lower waist circumference, higher HDL levels, and lower triglycerides. Using accelerometry, total MVPA was associated with a lower odds of all risk factors for the metabolic syndrome (23). In our study, we did not find any association of MVPA or $MVPA_{10+}$ with systolic blood pressure (SBP), diastolic blood pressure (DBP), fasting glucose levels, or hypertension or DM prevalence, although there was a borderline-significant association of MVPA with lower SBP (P = 0.03) and lower glucose levels (P = 0.05). Similarly, Atienza et al. (2), using NHANES 2003–2006

TABLE 2. Mean MVPA and $MVPA_{10+}$ ($min \cdot d^{-1}$) by sociodemographic variables.

	Men		Women		All	
	Total MVPA	$MVPA_{10+}$	Total MVPA	$MVPA_{10+}$	Total MVPA	$MVPA_{10+}$
Season of examination						
Fall	28.8 ± 23.6	7.1 ± 11.8	23.8 ± 19.6	7.9 ± 12.1	26.1 ± 21.6	7.6 ± 12.0
Winter	25.6 ± 22.2	5.3 ± 9.1	23.0 ± 15.8	8.6 ± 11.4	24.3 ± 19.4	6.9 ± 10.4
Spring	31.5 ± 20.1	6.9 ± 11.2	26.8 ± 20.2	10.5 ± 14.0	29.1 ± 20.3	10.9 ± 14.1
Summer	34.5 ± 20.1	9.7 ± 11.8	29.4 ± 21.5	11.7 ± 15.3	31.4 ± 21.1	11.7 ± 15.3
Nonsmokers	30.7 ± 21.8	7.7 ± 11.3	26.6 ± 19.8	10.3 ± 14.0	28.4 ± 20.8	9.2 ± 12.9
Current smokers	26.4 ± 22.0	4.2 ± 10.0	22.4 ± 20.7	6.0 ± 9.5	24.4 ± 21.4	5.1 ± 9.9
Education level						
≤High school degree	26.4 ± 25.9	4.8 ± 10.5	21.3 ± 20.1	6.8 ± 10.9	24.1 ± 23.5	5.7 ± 10.7
More than high school	28.9 ± 20.3	6.3 ± 9.6	25.0 ± 19.3	9.2 ± 13.6	26.7 ± 19.8	7.9 ± 12.1
Graduate degree	36.7 ± 21.7	12.2 ± 14.3	32.1 ± 20.3	13.4 ± 14.4	34.2 ± 21.0	12.9 ± 14.4
Employment status						
Homemaker or full-time student	30.2 ± 28.9	6.9 ± 13.6	27.1 ± 25.4	11.4 ± 17.1	27.2 ± 25.5	11.2 ± 16.9
Employed (full or part-time)	30.6 ± 21.1	7.1 ± 10.5	26.6 ± 19.1	9.7 ± 13.1	28.5 ± 20.2	8.5 ± 12.0
Unemployed/retired	26.8 ± 29.6	9.4 ± 18.0	20.6 ± 19.3	9.3 ± 14.4	23.4 ± 24.7	9.4 ± 16.1
Unemployed/on-leave for disability or health reasons	18.1 ± 13.8	8.2 ± 11.6	17.8 ± 19.0	7.4 ± 9.1	18.0 ± 15.9	7.8 ± 10.2
Self-reported health						
Fair	22.7 ± 15.7	6.7 ± 11.0	17.4 ± 22.0	5.1 ± 10.1	19.7 ± 19.6	5.8 ± 10.4
Good	29.0 ± 24.8	6.3 ± 11.5	19.1 ± 17.8	4.9 ± 8.9	24.2 ± 22.2	5.6 ± 10.3
Very good	28.0 ± 18.2	6.3 ± 9.2	26.2 ± 19.2	9.8 ± 13.5	27.0 ± 18.8	8.3 ± 11.9
Excellent	35.9 ± 24.0	10.1 ± 13.6	31.9 ± 20.5	13.9 ± 15.6	33.6 ± 22.1	12.3 ± 14.9

data, reported that $MVPA_{10+}$ was associated with continuous measures of SBP, BMI, waist circumference, HDL, triglycerides, glucose, and insulin but was not significantly associated with DBP, total or LDL cholesterol levels. However, there is emerging evidence that lower levels of activity, as well as sedentary behavior, may have associations with cardiometabolic health outcomes (3,14–16). Self-reported TV viewing time has also been reported to be associated with cardiometabolic risk factors and type 2 DM (12,35). In future studies, it will be important to assess the associations of lighter-intensity PA and sedentary behavior with CVD risk factors.

We observed significant associations between shorter bouts of MVPA and CVD risk factors, independent of $MVPA_{10+}$. Likewise, a recent study from the NHANES using accelerometry data reported that there may be metabolic health benefits associated with shorter bouts of MVPA. Strath et al. (34) reported that MVPA accumulated in <10 min was independently associated with BMI and waist circumference, after controlling for confounding variables. Our observed associations with BMI and waist circumference were similar to those in the NHANES. In NHANES, 10 $min \cdot d^{-1}$ of MVPA <10 min was associated with a 0.1 and 0.3 decrease in BMI and waist circumference, respectively. Although the current PA guidelines require that MVPA be accumulated in bouts of ≥10 min, given the high rates of sedentary behavior in the United States and the public health focus on increasing PA (22), it is crucial to know whether accumulating PA in shorter bouts is beneficial. There is limited prior evidence regarding the effect of shorter bouts of PA on CVD risk factors, independent of activity intensity and amount (24). The present investigation fills this gap in our current knowledge.

Although we did not formally test for differences by sex, we did observe that associations of MVPA levels with CVD risk factors were consistently stronger in women than in

TABLE 3. Relations of MVPA measures to CVD risk factors.

	Total MVPA[a]		$MVPA_{10+}$[b]		$MVPA_{<10}$[c]		
	β Coefficient	P	β Coefficient	P	β Coefficient	P	P for Comparison*
Triglycerides ($mg \cdot dL^{-1}$)	−3.8 (0.58)	<0.0001	−3.17 (0.81)	<0.0001	−4.42 (0.99)	<0.0001	0.48
HDL ($mg \cdot dL^{-1}$)	1.14 (0.18)	<0.0001	1.45 (0.34)	<0.0001	0.87 (0.26)	0.001	0.17
SBP (mm Hg)	−0.33 (0.15)	0.03	−0.19 (0.24)	0.44	−0.46 (0.23)	0.05	0.47
DBP (mm Hg)	−0.08 (0.10)	0.42	−0.16 (0.17)	0.35	0.01 (0.15)	0.96	0.55
Framingham risk score (%)	−0.19 (0.04)	<0.0001	−0.10 (0.07)	0.16	−0.28 (0.06)	<0.0001	0.08
Waist circumference (cm)	−1.01 (0.14)	<0.0001	−1.17 (0.20)	<0.0001	−0.86 (0.22)	<0.0001	0.36
BMI ($kg \cdot m^{-2}$)	−0.38 (0.05)	<0.0001	−0.46 (0.08)	<0.0001	−0.30 (0.09)	0.0007	0.27
Glucose ($mg \cdot dL^{-1}$)	−0.30 (0.16)	0.05	−0.29 (0.19)	0.12	−0.29 (0.28)	0.29	0.99
	Odds Ratio (95% CI)	P	Odds Ratio (95% CI)	P	Odds Ratio (95% CI)	P	
Hypertension	0.97 (0.91–1.023)	0.37	0.93 (0.84–1.04)	0.23	0.98 (0.89–1.08)	0.70	0.55
Obesity	0.85 (0.80–0.90)	<0.0001	0.83 (0.74–0.93)	0.0001	0.86 (0.78–0.94)	0.002	0.67
IGT	0.97 (0.92–1.03)	0.37	0.96 (0.87–1.07)	0.50	0.97 (0.90–1.06)	0.59	0.86
DM	0.93 (0.80–1.08)	0.36	0.86 (0.66–1.13)	0.28	0.97 (0.79–1.20)	0.81	0.48

β's and odds ratios are presented per 10 $min \cdot d^{-1}$ of MVPA. Statistical significance was set at $P < 0.001$ (Bonferroni correction for 12 CVD risk factors and 3 exposure variables.

[a] Adjusted for age, sex, average accelerometer wear time (total wear time/number of days worn), education level, and self-reported general health.

[b] Adjusted for age, sex, average accelerometer wear time, education level, self-reported general health, and $MVPA_{<10}$.

[c] Adjusted for age, sex, average accelerometer wear time, education level, self-reported general health, and $MVPA_{10+}$.

* P comparing β coefficient from $MVPA_{10+}$ model versus $MVPA_{<10}$ model.

TABLE 4. Relations of PA guideline compliance to risk factors.[a]

	≥150 min of $MVPA_{10+}$		≥150 min of Total MVPA	
	β Coefficient (SE)	***P***	**β Coefficient (SE)**	***P***
Triglycerides (mg·dL^{-1})	−10.7 (2.9)	0.0002	−12.8 (2.8)	<0.0001
HDL (mg·dL^{-1})	5.3 (1.1)	<0.0001	3.7 (0.72)	<0.0001
SBP (mm Hg)	−0.11 (0.86)	0.89	−1.73 (0.62)	0.005
DBP (mm Hg)	−0.23 (0.58)	0.69	−0.61 (0.42)	0.15
Framingham risk score (%)	−0.38 (0.18)	0.37	−0.93 (0.17)	<0.0001
Waist circumference (cm)	−3.5 (0.7)	<0.0001	−4.1 (0.6)	<0.0001
BMI (kg·m^{-2})	−1.31 (0.33)	<0.0001	−1.62 (0.23)	<0.0001
Glucose (mg·dL^{-1})	−0.53 (0.64)	0.41	−1.66 (0.64)	0.01
	Odds Ratio (95% CI)	***P***	**Odds Ratio (95% CI)**	***P***
Hypertension	0.96 (0.66–1.40)	0.84	0.78 (0.61–0.99)	0.04
Obesity	0.57 (0.40–0.82)	0.003	0.57 (0.46–0.71)	<0.0001
Impaired fasting glucose	0.98 (0.69–1.38)	0.91	0.69 (0.55–0.86)	0.001
DM	0.60 (0.24–1.53)	0.29	0.59 (0.36–0.98)	0.05

[a] β's and odds ratios are presented for compliance with guidelines (yes vs no). Adjusted for age, sex, education level, total accelerometer wear time, number of valid days worn, and self-reported general health.

men, although the reason for this is unclear. It could be due to underlying differences in the type or setting of PA by sex, biological differences in physiologic responses to MVPA, or other unmeasured confounding factors. In our sample, women tended to engage in more $MVPA_{10+}$ than men did, whereas men tended to accumulate MVPA in shorter bouts. Although prior studies have not reported more favorable effects of PA on CVD risk factors among women compared with men, a recent meta-analysis of 33 prospective cohort studies from Sattelmair et al. (30) observed significant effect modification by sex of the relationship between leisure time PA and risk of CHD. Comparing the most active with least active, they reported men had a 22% lower risk of CHD, whereas women had a 33% lower risk.

Our investigation is limited by the possibility of unmeasured confounders. PA may also occur in the presence of other healthy lifestyle factors, such as diet or physical fitness, which were not adjusted for. Our sample was primarily white and we do not yet have accelerometry data from other race or ethnic groups, but we plan on examining data from the multiethnic Framingham Omni cohort as it becomes available. Although the accelerometry is the state-of-the-art tool for measuring PA, because the Actical is worn at the hip, it is limited in capturing certain activities where the participant is stationary or has limited hip movement, such as strength training or bicycling. In addition, we cannot capture activity done while not wearing the device. Although the act of wearing the accelerometer may cause participants to increase their PA levels, accelerometers do not provide any feedback, making that less likely. Finally, although the most appropriate regression approach to classify PA intensity levels is not certain, we used methods similar to those previously published (36).

Strengths of our investigation include the use of a robust and objective measurement of PA. Currently, the most widely used methods for measuring PA in community-based studies are self-reported measures, typically ascertained via questionnaires. However, questionnaire information is subjective and prone to respondent and recall bias (11,32). In its 2008 report, the CDC Physical Activity Guidelines Advisory Committee noted that all of the studies included in its review used self-reported information on PA and many specified only leisure time activity, ignoring substantial components of PA (27).

Our investigation takes advantage of a well-characterized community-based sample and uses new technology to bridge a fundamental gap in our current knowledge regarding the health benefits of PA accumulated in shorter lengths of time and contributes to the evidence base for future public health recommendations and clinical guidelines for PA in adults. These results underscore the idea that "some activity is better than none" and may encourage inactive persons to become more active by allowing for PA in bouts <10 min.

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

EPIDEMIOLOGY

REFERENCES

1. American Geriatrics Society, British Geriatrics Society, American Academy of Orthopaedic Surgeons Panel on Falls Prevention. Guideline for the prevention of falls in older persons. *J Am Geriatr Soc*. 2001;49(5):664–72.
2. Atienza AA, Moser RP, Perna F, Dodd K, Ballard-Barbash R, Troiano RP, Berrigan D. Self-reported and objectively-measured activity related to biomarkers using NHANES. *Med Sci Sports Exerc*. 2010;43(5):815–21.
3. Camhi SM, Sisson SB, Johnson WD, Katzmarzyk PT, Tudor-Locke C. Accelerometer-determined moderate intensity lifestyle activity and cardiometabolic health. *Prev Med*. 2011;52(5): 358–60.
4. Carlson SA, Densmore D, Fulton JE, Yore MM, Kohl HW 3rd. Differences in physical activity prevalence and trends from 3 U.S. surveillance systems: NHIS, NHANES, and BRFSS. *J Phys Act Health*. 2009;6(1 suppl):S18–S27.

5. Crouter SE, Bassett DR Jr. A new 2-regression model for the Actical accelerometer. *Br J Sports Med*. 2008;42(3):217–24.
6. Dawber TR, Meadors GF, Moore FE Jr. Epidemiological approaches to heart disease: the Framingham Study. *Am J Public Health Nations Health*. 1951;41(3):279–81.
7. Esliger DW, Copeland JL, Barnes JD, Tremblay MS. Standardizing and optimizing the use of accelerometer data for free-living physical activity monitoring. *J Phys Act Health*. 2005;3:366–83.
8. Esliger DW, Finley E. KineSoft Software. 2010. (KineSoft, Saskatchewan, Canada.)
9. Folsom AR, Arnett DK, Hutchinson RG, Liao F, Clegg LX, Cooper LS. Physical activity and incidence of coronary heart disease in middle-aged women and men. *Med Sci Sports Exerc*. 1997;29(7):901–9.
10. Fried LP, Kronmal RA, Newman AB, et al. Risk factors for 5-year mortality in older adults: the Cardiovascular Health Study. *JAMA*. 1998;279(8):585–92.
11. Gardner AW, Poehlman ET. Assessment of free-living daily physical activity in older claudicants: validation against the doubly labeled water technique. *J Gerontol A Biol Sci Med Sci*. 1998; 53(4):M275–80.
12. Grontved A, Hu FB. Television viewing and risk of type 2 diabetes, cardiovascular disease, and all-cause mortality: a meta-analysis. *JAMA*. 2011;305(23):2448–55.
13. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1081–93.
14. Healy GN, Dunstan DW, Salmon J, et al. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. *Diabetes Care*. 2007;30(6):1384–9.
15. Healy GN, Dunstan DW, Salmon J, et al. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008; 31(4):661–6.
16. Healy GN, Wijndaele K, Dunstan DW, et al. Objectively measured sedentary time, physical activity, and metabolic risk: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Diabetes Care*. 2008;31(2):369–71.
17. Heil DP. Predicting activity energy expenditure using the Actical activity monitor. *Res Q Exerc Sport*. 2006;77(1):64–80.
18. Kannel WB, Sorlie P. Some health benefits of physical activity. The Framingham Study. *Arch Intern Med*. 1979;139(8):857–61.
19. Keysor JJ. Does late-life physical activity or exercise prevent or minimize disablement? A critical review of the scientific evidence. *Am J Prev Med*. 2003;25(3 suppl 2):129–36.
20. Larson EB, Wang L, Bowen JD, et al. Exercise is associated with reduced risk for incident dementia among persons 65 years of age and older. *Ann Intern Med*. 2006;144(2):73–81.
21. Liang KY, Zeger SL. Regression analysis for correlated data. *Annu Rev Public Health*. 1993;14:43–68.
22. Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic Impact Goal through 2020 and beyond. *Circulation*. 2010;121(4):586–613.
23. Metzger JS, Catellier DJ, Evenson KR, Treuth MS, Rosamond WD, Siega-Riz AM. Associations between patterns of objectively measured physical activity and risk factors for the metabolic syndrome. *Am J Health Promot*. 2010;24(3):161–9.
24. Murphy MH, Blair SN, Murtagh EM. Accumulated versus continuous exercise for health benefit: a review of empirical studies. *Sports Med*. 2009;39(1):29–43.
25. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. *Circulation*. 2007;116(9):1094–105.
26. NIH Consensus Development Panel on Physical Activity and Cardiovascular Health. Physical activity and cardiovascular health. *JAMA*. 1996;276(3):241–6.
27. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report*. Washington (DC): Department of Health and Human Services; 2008. 683 p.
28. Quan SF, Howard BV, Iber C, et al. The Sleep Heart Health Study: design, rationale, and methods. *Sleep*. 1997;20(12):1077–85.
29. Sacco RL, Gan R, Boden-Albala B, et al. Leisure-time physical activity and ischemic stroke risk: the Northern Manhattan Stroke Study. *Stroke*. 1998;29(2):380–7.
30. Sattelmair J, Pertman J, Ding EL, Kohl HW 3rd, Haskell W, Lee IM. Dose response between physical activity and risk of coronary heart disease: a meta-analysis. *Circulation*. 2011;124(7):789–95.
31. Sisson SB, Camhi SM, Church TS, Tudor-Locke C, Johnson WD, Katzmarzyk PT. Accelerometer-determined steps/day and metabolic syndrome. *Am J Prev Med*. 2010;38(6):575–82.
32. Sloane R, Snyder DC, Demark-Wahnefried W, Lobach D, Kraus WE. Comparing the 7-day physical activity recall with a triaxial accelerometer for measuring time in exercise. *Med Sci Sports Exerc*. 2009;41(6):1334–40.
33. Splansky GL, Corey D, Yang Q, et al. The Third Generation Cohort of the National Heart, Lung, and Blood Institute's Framingham Heart Study: design, recruitment, and initial examination. *Am J Epidemiol*. 2007;165(11):1328–35.
34. Strath SJ, Holleman RG, Ronis DL, Swartz AM, Richardson CR. Objective physical activity accumulation in bouts and nonbouts and relation to markers of obesity in US adults. *Prev Chronic Dis*. 2008;5(4):A131.
35. Thorp AA, Healy GN, Owen N, et al. Deleterious associations of sitting time and television viewing time with cardiometabolic risk biomarkers: Australian Diabetes, Obesity and Lifestyle (AusDiab) study 2004–2005. *Diabetes Care*. 2010;33(2):327–34.
36. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181–8.
37. Tucker JM, Welk GJ, Beyler NK. Physical activity in U.S.: adults compliance with the Physical Activity Guidelines for Americans. *Am J Prev Med*. 2011;40(4):454–61.
38. US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion. *Physical Activity and Health: A Report of the Surgeon General*. Atlanta (GA): Centers for Disease Control and Prevention; 1996. 278 p.
39. Wilson PW, D'Agostino RB, Levy D, Belanger AM, Silbershatz H, Kannel WB. Prediction of coronary heart disease using risk factor categories. *Circulation*. 1998;97(18):1837–47.
40. Yaffe K, Barnes D, Nevitt M, Lui LY, Covinsky K. A prospective study of physical activity and cognitive decline in elderly women: women who walk. *Arch Intern Med*. 2001;161(14):1703–8.