Association Between Change in Accelerometer-Measured and Self-Reported Physical Activity and Cardiovascular Disease in the Look AHEAD Trial

*Look AHEAD Study Group**

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OBJECTIVE

To conduct post hoc secondary analysis examining the association between change in physical activity. Measured with self-report and accelerometry, from baseline to 1 and 4 years and cardiovascular disease (CVD) outcomes in the Look AHEAD Trial.

RESEARCH DESIGN AND METHODS

Participants were adults with overweight/obesity and type 2 diabetes with physical activity. Data at baseline and year 1 or 4 (n = 1,978). Participants were randomized to diabetes support and education or intensive lifestyle intervention. Measures included accelerometry-measured moderate-to-vigorous physical activity (MVPA), self-reported physical activity, and composite (morbidity and mortality) CVD outcomes.

RESULTS

In pooled analyses of all participants, using Cox proportional hazards models, each 100 MET-min/week increase in accelerometry-measured MVPA from baseline to 4 years was associated with decreased risk of the subsequent primary composite outcome of CVD. Results were consistent for changes in total MVPA (hazard ratio 0.97 [95% CI 0.95, 0.99]) and MVPA accumulated in ≥10-min bouts (hazard ratio 0.95 [95% CI 0.91, 0.98]), with a similar pattern for secondary CVD outcomes. Change in accelerometry-measured MVPA at 1 year and self-reported change in physical activity at 1 and 4 years were not associated with CVD outcomes.

CONCLUSIONS

Increased accelerometry-measured MVPA from baseline to year 4 is associated with decreased risk of CVD outcomes. This suggests the need for long-term engagement in MVPA to reduce the risk of CVD in adults with overweight/obesity and type 2 diabetes.

Approximately 10% of adults in the U.S. has type 2 diabetes (1). By comparison, the International Diabetes Federation reports that the world-age standardized diabetes prevalence in 2019 for the region of North America and the Caribbean was

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11.1% and for the region of Europe was 6.3% (2). This results in increased medical costs, prevalence of other chronic conditions, such as cardiovascular disease (CVD), and risk of mortality (1). The Look AHEAD Study was designed to examine whether an intensive lifestyle intervention (ILI) designed to achieve weight loss through caloric restriction and increased physical activity decreased CVD morbidity and mortality among adults with overweight/obesity and type 2 diabetes (3).

The primary analyses for Look AHEAD showed that the ILI was not more effective than diabetes support and education (DSE) at reducing CVD outcomes (4). However, in a post hoc secondary analysis, persons who reduced their body weight by ≥10% had lower risk of outcomes of CVD (5). Moreover, it was shown that achieving a ≥2 MET (which is a multiple of resting energy expenditure that represents the energy expenditure of a specific task or physical activity) increase in cardiorespiratory fitness reduced the risk of some, but not all, outcomes of CVD. These findings may suggest that the magnitude of change in weight or fitness, which reflect physiological phenotypic factors, are important considerations relative to CVD risk in individuals with type 2 diabetes.

Another consideration would be to examine lifestyle behaviors that may also contribute to CVD risk. One such lifestyle behavior is physical activity. The 2018 Physical Activity Guidelines Advisory Committee Report concluded that there is strong evidence for an inverse association between volume, which takes into account the duration and intensity, of physical activity and risk of CVD mortality among adults with type 2 diabetes (6). Unique to this report is the conclusion that physical activity accumulated in bouts of any duration (e.g., ≥1 min) can contribute to reduced health risk. The conclusion that very short periods of physical activity contribute to the volume that is associated with reduced health risk is a paradigm shift from prior recommendations that physical activity be accumulated in bouts of ≥10 min. These findings were based primarily on cross-sectional findings and do not include studies examining whether physical activity bout duration (≥1 min vs. ≥10 min) influences CVD outcomes in individuals with type 2 diabetes. The use of bouts of activity as short as 1 min in duration may be of clinical relevance to patients with type 2 diabetes due to the potential presence of comorbid conditions and limitations in mobility and more disability (7).

While studies have demonstrated that increased physical activity is associated with fewer CVD outcomes, some studies have used self-reported measures of physical activity, whereas others have used more objective measures, such as accelerometry (8–12). A unique contribution of Look AHEAD is that physical activity was measured prospectively with both self-report and accelerometry, thus providing an opportunity to determine whether the association between physical activity and CVD outcomes is consistent across these different methods of assessment.

We performed post hoc secondary data analyses from the Look AHEAD Study to examine whether changes in physical activity over the 1st year and over the first 4 years was associated with a lower risk in CVD outcomes among individuals with type 2 diabetes using both accelerometry and self-reported measures of physical activity. We also examined whether the association varied when physical activity was considered in bouts ≥1 min or ≥10 min in duration, which is an important area of study based on recommendations outlined in the Physical Activity Guidelines Advisory Committee Report (6).

RESEARCH DESIGN AND METHODS

Participants

Look AHEAD was a multicenter, randomized controlled trial designed to test the effects on CVD morbidity and mortality of an ILI intended to produce 5–10% weight loss (3). This article reports on CVD outcomes at the end of the intervention period (14 September 2012) when the median follow-up was 9.6 years (interquartile range, 8.9 to 10.3). The eligibility criteria have been previously reported (3,4). Briefly, eligibility criteria included 45–76 years of age, type 2 diabetes confirmed by use of diabetes medication or physician report, and BMI ≥25 kg/m^2 or ≥27 kg/m^2 among those receiving insulin therapy. Exclusion criteria included hemoglobin A_{1c} levels >11% (>96.7 mmol/mol); systolic blood pressure >160 mmHg; diastolic blood pressure >100 mmHg; plasma triglyceride levels >600 mg/dL; inability to complete a maximal graded exercise test; or inability to complete diet and activity self-monitoring during a 2-week behavioral run-in period.

Participants included in the analysis were a subset from the Look AHEAD Study who engaged in the substudy to measure physical activity using accelerometry and self-report via a questionnaire. The substudy was conducted at 8 of the clinical sites, which recruited 2,627 of the total 5,145 participants (51.1%) in Look AHEAD. To allow for assessment of change in physical activity measured by accelerometry, participants needed valid accelerometry data at baseline and at either or both year 1 or year 4, which resulted in a sample of 1,978 (75.3% of the randomized sample available at the clinical sites participating in this substudy). Analysis of physical activity via self-report included 1,978 participants who provided a baseline measure of physical activity and at year 1, year 4, or both year 1 and year 4 with descriptive data provided in Table 1.

Interventions

Participants were randomly assigned to an ILI or DSE group as previously described (3,13,14). Briefly, the ILI group included a combination of group and individual sessions, contact via telephone or e-mail, motivational campaigns, and refresher campaigns. For months 1–6, the intervention included group and individual sessions. During months 7–12, the ILI group were offered two group sessions and one individual session per month. Monthly in-person contact and one telephone or e-mail contact were offered during months 13–48, along with two annual refresher campaigns.

The dietary intervention focused on reducing energy intake to 1,200–1,800 kcal/day, with maximum dietary fat intake prescribed at 30% of total energy intake with 10% consumed as saturated fat. Commercially available liquid shakes and snack bars were provided to replace two meals per day at no cost to participants during weeks 3–20, and thereafter, one shake and one snack bar per day were provided, along with detailed meal plans of conventional foods for their daily meals.

Table 1—Characteristics of the study sample

Variable	Overall study sample (*N* = 5,145)	Participants not included in analyses (*N* = 3,167)	Participants included in analyses (*N* = 1,978)	*P* value*	Participants with baseline and year 1 accelerometry data only (*N* = 198)	Participants with baseline and year 4 accelerometry data only (*N* = 352)
Age at randomization (years)	58.7 (6.8)	58.5 (6.8)	59.1 (6.8)	0.0013	59.8 (6.7)	57.7 (7.0)
Female, *N* (%)	3,063 (59.5)	1,930 (60.9)	1,133 (57.3)	0.0093	114 (57.6)	211 (59.9)
Baseline history of CVD, *N* (%)	714 (13.9)	410 (12.9)	304 (15.4)	0.0145	41 (20.7)	41 (11.6)
Diabetes duration at baseline (years)	6.8 (6.5)	6.7 (6.6)	6.9 (6.5)	0.3733	8.0 (6.6)	6.7 (6.5)
Baseline insulin use, *N* (%)	792 (16.0)	493 (16.2)	299 (15.6)	0.5766	35 (18.0)	50 (14.7)
Baseline BMI (kg/m^2)	35.9 (5.9)	35.7 (5.8)	36.4 (6.0)	<0.0001	36.7 (5.7)	37.1 (6.1)
Baseline weight (kg)	100.7 (19.3)	99.4 (19.3)	102.8 (19.0)	<0.0001	104.0 (19.1)	104.2 (19.7)
Year 1 weight change from baseline (kg)	−4.8 (7.6)	−4.6 (7.5)	−5.1 (7.7)	0.0355	−4.6 (7.9)	−5.0 (7.3)
Year 4 weight change from baseline (kg)	−3.1 (8.8)	−3.0 (8.9)	−3.3 (8.8)	0.2199	−2.2 (7.6)	−3.6 (9.7)
Baseline cardiorespiratory fitness (maximal METS)	7.2 (2.0)	7.3 (2.0)	7.1 (1.9)	0.0037	6.9 (1.9)	7.2 (1.9)

Data are mean (SD) unless otherwise indicated. **P* value represents the comparison of participants included and not included in the analyses.

Participants were instructed to progressively increase nonsupervised physical activity from 50 min/week to at least 175 min/week by week 26 of the intervention. Physical activity accumulated in bouts of ≥10 min was counted toward the activity goal. Physical activity was recommended to be performed at a moderate-to-vigorous intensity, which was anchored as activity performed at an intensity similar to brisk walking. Resistance exercise was encouraged and could contribute to up to 25% of the prescribed activity goal each week.

Participants assigned to DSE were offered three group sessions during years 1–4 that focused on diet, physical activity, or social support, but did not include specific behavioral strategies regarding diet or physical activity that would result in weight loss or change in fitness. For both the ILI and DSE groups, medical care and diabetes treatment continued to be provided by the participant's health care provider. Only temporary adjustments to diabetes medications were permitted by the local site to prevent episodes of hypoglycemia that may result from the intervention.

Physical Activity

Physical activity was assessed using a triaxial accelerometer (RT3; Stayhealthy, Inc., Monrovia, CA). The accelerometry methods within the Look AHEAD Study have been previously described (15,16). The accelerometer was worn vertically at the waist at the anatomical location of the anterior iliac spine. The accelerometer was set in the three axis and 1-min epoch mode for data collection. Data for a given day were considered valid if the accelerometer was worn for ≥10 h on that day, which is consistent with previously published recommendations for the use of an accelerometer to measure physical activity (15,16). Participants were instructed to wear the accelerometer for a period of 7 days, and there had to be at least 4 valid days of accelerometry data to be included in the analysis. These data were used to identify minutes that met the criteria for moderate-to-vigorous physical activity (MVPA), which was defined as ≥3 METs. Total MVPA was defined as the sum of all minutes that achieved the ≥3 METS criteria, whereas bouted MVPA was defined as the sum of all minutes that

Table 2—Accelerometry and self-reported physical activity at baseline, 1 year, and 4 years

	Baseline absolute value	1 year		4 years	
		Absolute value	Change from baseline	Absolute value	Change from baseline
Accelerometry-measured total MVPA (MET-min/week)	1,489.0 (1,178.8) (N = 1,978)	1,484.3 (1,385.9) (N = 1,626)	13.7 (1,403.8) (N = 1,626)	1,219.5 (2,328.1) (N = 1,780)	−292.5 (2,417.2) (N = 1,780)
Accelerometry-measured MVPA in bouts ≥10 min (MET-min/week)	432.4 (733.5) (N = 1.978)	567.0 (971.2) (N = 1,626)	133.8 (961.8) (N = 1,626)	431.6 (2,131.2) (N = 1,780)	−6.0 (2,177.3) (N = 1,780)
Self-reported physical activity (MET-min/week)	519.9 (684.6) (N = 1,971)	811.8 (898.5) (N = 1,908)	290.9 (910.6) (N = 1,901)	665.5 (839.4) (N = 1,864)	142.9 (902.5) (N = 1,858)

Data are mean (SD).

achieved the ≥3 METS criteria and were also accumulated in bouts of ≥10 min.

Leisure-time physical activity (LTPA) was assessed with the Paffenbarger Physical Activity Questionnaire as previously described (17). This was completed during a structured interview in which participants self-reported the flights of stairs climbed, number of city blocks walked, and other fitness, sport, and recreational activities performed. The questionnaire assessed the prior week's LTPA. These data were used to compute kilocalories per week of LTPA, which were then converted to MET-min/week assuming a minimum energy expenditure of 3 METs/min.

CVD Outcomes

Analyses were restricted to prespecified outcomes for the Look AHEAD Study (4). These outcomes were adjudicated by a committee blinded to randomized group assignment. The primary CVD outcome was defined as first occurrence after study enrollment of nonfatal myocardial infarction or stroke, hospitalized angina, or CVD death. There were three secondary outcomes that included: *1*) CVD death, nonfatal myocardial infarction, or nonfatal stroke; *2*) all-cause death, nonfatal myocardial infarction, nonfatal stroke, or hospitalization for angina; and *3*) all-cause death, nonfatal myocardial infarction, nonfatal stroke, hospitalization for angina; and hospitalization for congestive heart failure, coronary artery bypass graft, carotid endarterectomy, or peripheral vascular disease. For the analyses presented, we examined CVD outcomes that occurred from the end of year 1 through the end of the intervention period and from the end of year 4 through the end of the intervention period, which included a maximum of 13.5 years of follow-up (4).

Statistical Analysis

Post hoc secondary data analysis of the Look AHEAD Study data was performed using SAS (version 9.4). All analyses were conducted by M.P.W. with additional input on statistical analyses from W.L. Analysis included participants who were in the substudy that included accelerometry-measured physical activity and who provided a self-reported measure of physical activity at baseline and at either year 1 or 4 of the intervention. Participants from the ILI and DSE treatment groups were combined in these analyses.

Descriptive statistics include mean and SD or median and interquartile range depending on the normality of continuous variables or frequency and percentage for categorical variables. Differences in demographic characteristics between participants included in the analyses and the other Look AHEAD participants who were not in the substudy and therefore excluded from analyses are assessed using the χ^2 test, two-sample t test, or Wilcoxon rank sum test for categorical, normal, and nonnormal variables, respectively. Spearman correlation coefficients are used to examine bivariate associations between two continuous variables.

Separate Cox proportional hazards models (hazard ratios [HRs] [95% CI]) were fitted to examine the relationships between each 100 MET-min/week change in either accelerometry-measured physical activity or self-reported LTPA and the primary and each of the three secondary CVD outcomes. To ensure proper temporal associations, analyses examined the relationship between the change in physical activity at 1 year and the CVD outcomes occurring after 1 year and the relationship between the change in physical activity at 4 years and the CVD outcomes occurring after 4 years. Effects for changes in total MVPA and changes in MVPA accumulated in bouts of ≥10 min were examined separately. For these analyses, Cox proportional hazards models adjusted for treatment group, age, baseline physical activity, sex, baseline history of CVD, duration of diabetes at baseline, use of insulin or other diabetes medication, baseline weight, and change in weight at 1 or 4 years matching the assessment time period for change in physical activity.

RESULTS

Baseline descriptive statistics of the subset of participants from the main Look AHEAD Study included in these post hoc secondary analyses are shown in Table 1. Compared with the overall study sample, the subset in these analyses were older and weighed more, less likely to be female, and more likely to have had CVD at baseline. Table 1 also presents descriptive statistics for participants who provided only baseline and 1-year or only baseline and 4-year physical activity data. Data for accelerometry-measured and self-reported physical activity are shown in Table 2.

Correlations between the various measures of physical activity are shown in Table 3. The relationship between the change from baseline to 1 year for accelerometry-measured total MVPA and MVPA performed in bouts of ≥10 min was $r = 0.896$ ($P < 0.0001$), and the relationship for change from baseline to 4 years was $r = 0.938$ ($P < 0.0001$). The relationship between self-reported physical activity and accelerometry-measured total MVPA for the change from baseline to 1 year was $r =$

Table 3—Pearson correlations between change in accelerometry-measured and self-reported physical activity

	Accelerometry-measured total MVPA		Accelerometry-measured MVPA in bouts ≥10 min	
	Change from baseline to 1 year	Change from baseline to 4 years	Change from baseline to 1 year	Change from baseline to 4 years
Accelerometry-measured total MVPA				
Change from baseline to 1 year				
Change from baseline to 4 years	$r = 0.191$ $P < 0.0001$ $N = 1{,}428$			
Accelerometry-measured MVPA in bouts ≥10 min				
Change from baseline to 1 year	$r = 0.896$ $P < 0.0001$ $N = 1{,}626$	$r = 0.149$ $P < 0.0001$ $N = 1{,}428$		
Change from baseline to 4 years	$r = 0.097$ $P = 0.0002$ $N = 1{,}428$	$r = 0.938$ $P < 0.0001$ $N = 1{,}780$	$r = 0.113$ $P < 0.0001$ $N = 1{,}428$	
Self-reported physical activity				
Change from baseline to 1 year	$r = 0.114$ $P < 0.0001$ $N = 1{,}591$	$r = 0.026$ $P = 0.2888$ $N = 1{,}710$	$r = 0.155$ $P < 0.0001$ $N = 1{,}591$	$r = 0.023$ $P = 0.3514$ $N = 1{,}710$
Change from baseline to 4 years	$r = 0.033$ $P = 0.1944$ $N = 1{,}511$	$r = 0.031$ $P = 0.1967$ $N = 1{,}762$	$r = 0.070$ $P = 0.0064$ $N = 1{,}511$	$r = 0.041$ $P = 0.0828$ $N = 1{,}762$

0.114 ($P < 0.0001$) and for the change from baseline to 4 years was $r = 0.031$ ($P = 0.1967$). For accelerometry-measured MVPA performed in bouts of ≥10 min and self-reported physical activity, the relationship for change from baseline to 1 year was 0.155 ($P < 0.0001$) and for the change from baseline to 4 years was $r = 0.041$ ($P = 0.0828$).

Table 4 presents the primary and secondary CVD outcomes that occurred after the 1st year of intervention and the primary and secondary CVD events that occurred after the 4th year of intervention. For the primary outcome, the person-years of follow-up were 17,342 for the year 1 analysis and 17,124 for the year 4 analysis. Continuous physical activity data measured with accelerometry were analyzed to examine the association between a 100 MET-min/week increase in MVPA and the primary and secondary outcomes after 1 and 4 years (Table 4). For total MVPA measured via accelerometry, the change in physical activity from baseline to 1 year was not associated with either the primary or the secondary outcomes that occurred after the 1st year. However, for the change in total MVPA from baseline to year 4, each 100 MET-min/week increase in total MVPA was associated with a reduction in risk for both the primary (HR 0.973 [95% CI 0.953, 0.993]) and each of the secondary outcomes (secondary outcome 1: HR 0.949 [95% CI 0.923, 0.976]; secondary outcome 2: HR 0.967 [95% CI 0.950, 0.985]; and secondary outcome 3: HR 0.974 [95% CI 0.958, 0.990]) that occurred after the 4th year. Separate analyses were performed for the ILI and DSE groups and the pattern of results was similar (data not shown).

Analysis of accelerometry-measured MVPA performed in bouts of ≥10 min (Table 4) showed a similar pattern as that observed for total MVPA. For MVPA performed in bouts of ≥10 min measured via accelerometry, the change in physical activity from baseline to 1 year was not associated with either the primary or the secondary outcomes that occurred after the 1st year. However, for the change in MVPA performed in bouts of ≥10 min from baseline to year 4, each 100 MET-min/week increase in physical activity was associated with a reduction in risk for both the primary (HR 0.946 [95% CI 0.909, 0.984]) and each of the secondary outcomes (secondary outcome 1: HR 0.895 [95% CI 0.841, 0.953]; secondary outcome 2: HR 0.940 [95% CI 0.908, 0.973]; secondary outcome 3: HR 0.946 [95% CI 0.917, 0.976]) that occurred after the 4th year. Separate analyses were performed for the ILI and DSE groups, and the pattern of results was similar (data not shown).

The analyses of the associations between accelerometry-measured MVPA and CVD events were repeated, including only those participants who had accelerometry-measured physical activity at both year 1 and 4. The results of these analyses were similar to the data presented in Table 4 (data not shown).

Analyses were also performed on self-reported LTPA to assess the relationship with CVD outcomes (Table 4). These analyses showed that there was no relationship with either the primary or secondary outcomes with each 100 MET-min/week increase in physical activity, and these findings were consistent for analyses of the change from baseline to 1 year and baseline to 4 years. Separate analyses were performed for the ILI and DSE groups, and the pattern of results was similar (data not shown).

CONCLUSIONS

We performed post hoc secondary data analyses to examine whether changes in physical activity over the 1st year and over the first 4 years of Look AHEAD were associated with a lower risk of CVD outcomes. These analyses demonstrated that an increase in accelerometry-measured physical activity for each

Table 4—HRs for primary and secondary cardiovascular disease outcomes based on 1-year and 4-year change in physical activity (N = 1,978)

	1-year change in physical activity per increase of 100 MET-min/week					
	Change in accelerometery-measured total MVPA		Change in accelerometry-measured MVPA in bouts ≥10 min		Change in self-reported measured physical activity	
CVD outcomes	Events (*N*)*	HR (95% CI)**	Events (*N*)*	HR (95% CI)**	Events (*N*)*	HR (95% CI)**
Primary outcome#	247 (1,552)	1.002 (0.992, 1.013)	247 (1,552)	1.001 (0.985, 1.017)	277 (1,817)	1.004 (0.989, 1.019)
Secondary outcome 1$	174 (1,555)	0.991 (0.975, 1.007)	174 (1,555)	0.989 (0.966, 1.013)	197 (1,821)	1.000 (0.981, 1.019)
Secondary outcome 2^	318 (1,552)	0.999 (0.989, 1.009)	318 (1,552)	0.997 (0.982, 1.012)	360 (1,817)	1.000 (0.987, 1.014)
Secondary outcome 3&	375 (1,548)	0.994 (0.983, 1.004)	375 (1,548)	0.990 (0.974, 1.006)	425 (1,811)	0.998 (0.986, 1.011)
	4-year change in physical activity per increase of 100 MET-min/week					
Primary outcome#	164 (1,610)	0.973 (0.953, 0.993)	164 (1,610)	0.946 (0.909, 0.984)	173 (1,685)	1.002 (0.982, 1.022)
Secondary outcome 1$	127 (1,655)	0.949 (0.923, 0.976)	127 (1,655)	0.895 (0.841, 0.953)	134 (1,730)	0.985 (0.960, 1.011)
Secondary outcome 2^	225 (1,610)	0.967 (0.950, 0.985)	225 (1,610)	0.940 (0.908, 0.973)	236 (1,685)	0.989 (0.971, 1.008)
Secondary outcome 3&	259 (1,577)	0.974 (0.958, 0.990)	259 (1,577)	0.946 (0.917, 0.976)	271 (1,650)	0.993 (0.977, 1.010)

*Events for 1-year analyses occurred between year 1 and a maximum of 13.5 years of follow-up; events for 4-year analyses occurred between year 4 and a maximum of 13.5 years of follow-up. **Controlling for treatment group, age, baseline physical activity, sex, baseline history of CVD, duration of diabetes at baseline, using insulin or other diabetes medication, baseline weight, and change in weight. #First occurrence after study enrollment of nonfatal myocardial infarction or stroke, hospitalized angina, or CVD death. $CVD death, nonfatal myocardial infarction, or nonfatal stroke. ^All-cause death, nonfatal myocardial infarction, nonfatal stroke, or hospitalization for angina. &All-cause death, nonfatal myocardial infarction, nonfatal stroke, hospitalization for angina; hospitalization for congestive heart failure, coronary artery bypass graph, carotid endarterectomy, or peripheral vascular disease.

100 MET-min/week (∼30 min of brisk walking/week) from baseline to year 4 in people with overweight/obesity and type 2 diabetes was associated with a 5–10% reduction in risk for the primary and secondary CVD outcomes that occurred after year 4. Self-reported LTPA was not associated with reductions in these outcomes, nor was change in physical activity across the 1st year of the intervention. This suggests that physical activity needs to be sustained for a relatively long period to decrease risk of CVD outcomes in participants with type 2 diabetes. However, these results should be interpreted with caution given they were not based on prespecified data analysis from the Look AHEAD Study and therefore are hypothesis generating and require replication.

The 2018 Physical Activity Guidelines Advisory Committee concluded there is strong evidence of an association between physical activity and CVD mortality and incidence (6,18), with the majority of the evidence supporting the association based on self-reported physical activity. In contrast, in this study, the change in self-reported physical activity was not significantly associated with either the primary or secondary outcomes. Rather, the significant associations reported were observed for change in accelerometry-measured physical activity data from baseline to year 4. Though the specific reason for the associations only being observed with change in accelerometry cannot be determined, one possible explanation is that the self-report of physical activity was not sensitive enough to detect the array of physical activities performed that may be associated with a reduction in CVD risk. For example, the questionnaire did not specifically query about household, occupational, or other activities that the participant performed that were not considered sport, fitness, or recreational in nature, although these activities may have been detected by the accelerometer.

The finding that an increase in MVPA needs to be sustained across a relatively long period of time to markedly decrease adverse CVD outcomes end points in patients with type 2 diabetes is consistent with other literature. Seminal research conducted by Paffenbarger et al. (10) reported on reductions in coronary heart disease mortality with increased self-reported physical activity over a 9-year follow-up period. A meta-analysis that included studies with a mean follow-up period of 11.3 years (HR 0.69 [95% CI 0.61, 0.77]) showed reduced CVD mortality with self-reported physical activity (9). Collectively, these findings may suggest the need for enhanced intervention strategies that result in a sustained increase in physical activity across periods of >1 year to favorably impact CVD-related outcomes, such as those in the Look AHEAD Study. These findings also suggest the need for strategies to help people adopt and maintain sufficient amounts of physical activity to impact CVD-related outcomes in patients with type 2 diabetes. The importance of this is highlighted in this study in which it was shown that the intervention was effective at increasing physical activity from baseline to year 1, but this increase, on average, was not sustained at year 4. Unfortunately, reviews of the literature do not identify studies of ≥4 years that may inform the most effective intervention strategies to achieve and sustain this level of MVPA (6).

A unique contribution of these analyses is that results are presented for total MVPA and for MVPA accumulated in bouts of ≥10 min. It has been recommended that longitudinal research is needed to examine whether bout length of physical activity influences that association with health outcomes (6,19). Based on the analyses of the continuous physical activity data, it appears that an increase in total MVPA from baseline to year 4, regardless of length of the activity bout, is associated with a reduction in CVD outcomes. However, this study does not allow for appropriate examination of whether total MVPA or MVPA accumulated in bouts ≥10 min may differentially contribute to a reduction in CVD outcomes. This may require additional prospective or randomized studies that are appropriately designed to examine this public health question.

This study has a number of strengths. The Look AHEAD Study included predetermined primary and secondary CVD outcomes, had a relatively large sample size, included both accelerometry-measured and self-reported physical activity, and conducted follow-up assessments of physical activity at both 1 and 4 years. However, this study also has limitations that need to be considered when interpreting the implications of these findings. The findings are based on secondary data analyses that are not based on the randomized design, which may introduce selection bias and unmeasured confounding. While the analyses controlled for randomized group assignment and change in body weight, this may not have fully accounted for the additional influence beyond physical activity within the ILI and DSE groups on the CVD-related outcomes examined. Therefore, we analyzed the data separately for the ILI and DSE groups and found that the pattern of results was similar. This study included a subsample of the full Look AHEAD cohort who participated in the physical activity substudy and provided sufficient data for analysis, and there were some demographic differences between those in this substudy compared with those not in this substudy, which may have contributed to bias. Moreover, those participants with accelerometry only at 1 year had a higher history of CVD, greater use of insulin, and a lower fitness level at baseline compared with those with accelerometry only at year 4, which may have also contributed to bias. While this study included both accelerometry and self-reported measures of physical activity, the device and the questionnaire used may not have been sensitive to detecting all forms of physical activity, which may have resulted in an underestimation of physical activity. Follow-up measures of physical activity were only obtained at 1 and 4 years, which limits the ability to conduct more sensitive analyses of patterns of physical activity that occurred during those interim periods. Moreover, physical activity was assessed over a period of 7 days at each assessment point, which may not accurately represent the broader pattern of physical activity for an individual.

In summary, in secondary analyses of data from Look AHEAD, change in accelerometer-measured MVPA from baseline to year 4, but not change from baseline to year 1, was associated with reduced risk of CVD-related outcomes. This may suggest that sustained MVPA over a period of >1 year, and for as many as 4 years, may be needed to improve the risk of CVD outcomes. While it is important to replicate these findings in appropriately designed randomized or prospective trials, they have important clinical implications for CVD prevention in adults with overweight/obesity and type 2 diabetes. To improve the risk of CVD for persons with overweight/obesity and type 2 diabetes, increasing MVPA may need to be viewed as not simply a short-term change in behavior but as an ongoing commitment to a physically active lifestyle.

APPENDIX

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