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Four-Year Physical Activity Levels among Intervention Participants with Type 2 Diabetes

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Abstract

Physical activity (PA) has numerous health benefits, particularly for those with diabetes. However, rates of long-term PA participation are often poor.

Purpose—This study examined the effect of an intensive lifestyle intervention (ILI) on objectively-assessed PA over a 4-year period among older adults with type 2 diabetes.

Methods—Data from 2400 participants (age: 59.3±6.9 yrs; BMI: 36.1±5.9 kg/m^2) with accelerometry data from the Look AHEAD trial were included in the analyses. Participants randomized to ILI were instructed to reduce caloric intake and progress to ≥175 min/wk of moderate-to-vigorous intensity PA (MVPA), while those randomized to Diabetes Support and Education (DSE) served as the control group. PA was measured at baseline, Year 1, and Year 4 using an RT3 accelerometer and bout-related MVPA (PA ≥3 METs, accumulated in bouts of ≥10 minutes in duration) was calculated.

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Results—Despite no differences at baseline (ILI: 93.4±152.7 vs. DSE: 88.4±143.6 min/wk), bout-related MVPA was significantly greater in ILI compared to DSE at Year 1 (151.0±213.5 vs. 87.5±145.1 min/wk, p<0.0001) and Year 4 (102.9±195.6 vs. 73.9±267.5 min/wk, p<0.001), and more ILI participants achieved ≥175 min/week at Year 1 (29.1% vs. 16.3%, p<0.001) and Year 4 (18.3% vs. 10.0%, p<0.001). Forty-one percent of ILI participants who achieved ≥175 min/wk at Year 1, maintained this threshold of PA at Year 4. However, the majority of ILI participants never achieved the ≥175 min/wk threshold.

Conclusions—When measured objectively and compared to DSE, ILI engaged in significantly more bout-related MVPA over a 4-year period. However, future intervention strategies should target the large percentage of individuals who fail to reach the MVPA goal as result of a lifestyle intervention.

Keywords

exercise; Look AHEAD Trial; lifestyle intervention; weight loss intervention

INTRODUCTION

The psychological and physiological health benefits of regular physical activity (PA) are well documented. Not only is regular PA inversely associated with heart disease, type 2 diabetes, and certain forms of cancer (22), but regular PA may be particularly important among older adults since PA is associated with greater bone mass, reduced rates of falling, prevention of sarcopenia, and lower rates of cognitive decline and dementia (3). However despite these numerous health benefits, few adults, and even fewer older adults are adequately active (20, 28). Of further concern is that those who may receive the greatest benefit from regular PA participation (e.g., individuals with chronic health conditions such as obesity or diabetes), are also those engaging in the least amount of PA (19).

According to the American College of Sports Medicine (ACSM) and the American Heart Association (AHA), both older adults (i.e., >65 or 50-64 years of age with clinically significant chronic conditions and/or functional limitations) (20) and those with type 2 diabetes should engage in ≥150 min/week of moderate-to-vigorous intensity PA (MVPA) to maintain cardiorespiratory fitness and improve health, and this should be accumulated in bouts of ≥10 minutes in duration (4, 10, 20). This volume of exercise is equivalent to ≥500-1000 MET-min/week (7). However, there also appears to be a dose-response relationship between PA and health outcomes, suggesting that even greater improvements in health can be observed among those exceeding these recommendations (5, 7).

Given that actual PA levels fall well below the national PA recommendations for older adults, particularly those with obesity or type 2 diabetes, it is important to investigate how PA in older adults with obesity and comorbidities is altered within the context of intervention trials. To date, exercise interventions in general are shown to significantly increase PA in the short-term (i.e., < 6 months); however the results are less robust when studied longer-term (i.e., > months) (8). Similar findings have been observed when PA is targeted within the context of a behavioral weight loss program (14, 16, 26). However, the majority of these studies have been limited by relatively short follow up periods (e.g., 12-24 months) and reliance on self-report PA measures. Moreover, previous studies have predominately enrolled only participants who are inactive at baseline, thus not allowing for the examination of whether baseline levels of PA influence rates of PA adoption and maintenance throughout an intervention period (14-16). Further, findings from these studies are typically presented as group-level means, therefore limiting our understanding of how these interventions impact PA at the individual level. For example, it is clinically important that we begin to understand the number and characteristics of individuals, who are adopting and maintaining (vs. not adopting or not maintaining) recommended levels of PA throughout an intervention/follow-up period. A greater knowledge of these individual differences could lead to better tailoring of interventions and an improved understanding of who interventions should target to have the greatest impact.

We report data from the Look AHEAD study overcoming these previous limitations by examining the long-term (4-year) effects of an intensive lifestyle intervention on objectively-assessed PA in older, overweight and obese individuals with type 2 diabetes, a population at a high risk for being inactive. This study compares a subgroup of individuals randomized to the intensive lifestyle intervention (ILI) of the Look AHEAD trial to those randomized to the Diabetes Support and Education (DSE; control group) on overall MVPA levels as measured by accelerometry and the percentage of individuals achieving the Look AHEAD study PA goal of ≥175 min/week of bout-related MVPA. Further we stratify participants by baseline, 1-year, and 4-year MVPA levels, examine adherence to national PA recommendations, and examine whether there are baseline demographic differences between those who adopt and maintain prescribed PA levels compared to those who do not.

METHODS

Participants

Participants were enrolled in the Look AHEAD Study, a multi-center, randomized trial examining the effect of an intensive lifestyle intervention on the primary and secondary prevention of cardiovascular disease in overweight and obese adults with Type 2 diabetes. In total, 5,145 individuals were randomized across 16 clinical sites in the United States and full inclusion/exclusion criteria have been reported elsewhere (23-24). In short, participants had type 2 diabetes, were 45-76 years of age, and had a body mass index (BMI) ≥25kg/m^2 (or ≥27kg/m^2 if taking insulin). Individuals also had to pass a maximal exercise test at baseline and a test of behavioral adherence, which included recording daily information about diet and physical activity over a two-week period (13, 31). The following analyses only include those 2,627 participants from the 8 clinical sites which were selected to be part of the accelerometer sub-study. Descriptive data for the accelerometer subgroup (in comparison to the entire Look AHEAD sample) have been reported previously (12). All participants provided written informed consent, and study procedures were approved by each center’s institutional review board.

Treatment conditions

Look AHEAD participants were randomly assigned to an intensive lifestyle intervention or Diabetes Support and Education, which served as the control group. Full descriptions of the

ILI and DSE conditions have been provided previously (29). The following descriptions focus on the first 4 years of the trial.

Intensive Lifestyle Intervention

Intervention frequency—During Months 1-6, ILI participants had the opportunity to attend three weekly group sessions and one individual counseling session per month, which was reduced to two group and one individual session per month in Months 7-12. During Years 2-4, participants had one, in-person, individual meeting (20-30 min) with their interventionist, with a second individual contact by telephone (10-15 min) or email, two weeks later. Further, in Years 2-4, monthly group sessions were offered. Each year participants were also able to participate in at least one refresher group (6-8 weeks in duration; organized around a special weight loss and/or PA theme) and one national campaign (8-10 weeks in duration; challenged participants to meet specific goals).

Dietary component—In Year 1, participants in ILI were prescribed a calorie goal of 1200-1800 kcal/day depending upon initial body weight and were instructed to consume <30% of total calories from dietary fat. Meal replacements were provided and participants were instructed to replace two meals and one snack per day with a meal replacement product for months 1-6 and one meal and one snack per day during months 7-12. In Years 2-4, participants had individualized calorie goals based upon their desire to maintain their weight loss, lose more weight (if BMI was >23 kg/m^2), or reverse weight gain.

Physical activity component—Participants were given a home-based physical activity regimen designed to gradually increase structured activity to ≥175 min/week within the first 6 months, with a further increase for participants who met this goal. While <15% of intervention lessons in the first year focused specifically on PA, many of the behavioral lessons (e.g., stimulus control, goal setting, self-monitoring, problem solving, etc.) were applied to both diet and PA. In Years 2-4, participants were encouraged to continue to exercise at least 175 min/week. While a goal of ≥150 min/week was used in the Diabetes Prevention Program and is also the public health recommendation for PA, Look AHEAD took a more ambitious goal and targeted ≥175 min/week because of the reported findings that higher levels of PA may be associated with greater weight loss maintenance (30). Further, the majority of exercise was home-based, although some refresher courses or campaigns that were performed in Years 2-4 centered around PA and thus participants would exercise at the clinic (e.g., yoga session, circuit training lesson, resistance training, etc.).

Diabetes Support and Education—During Years 1-4, DSE participants were invited to attend three, 1-hour group meetings per year. These meetings were mainly informational and discussed diet, PA, and social support but did not provide any specific behavioral strategies for adopting the recommendations discussed.

Objective assessment of physical activity

The RT3 triaxial accelerometer (StayHealthy, Monrovia, CA) was used to provide an objective measure of PA at baseline, Year 1, and Year 4. Participants were instructed to wear this waist-mounted device for seven consecutive days during waking hours, removing it only for periods of bathing, showering, or other water-based activities. Participants were also instructed not to alter their typical PA pattern while wearing this device. The data collection mode for the accelerometer was set in the three-axis and one-min epoch mode and various quality control procedures were implemented (18). If subjects did not have complete data, an attempt was made to have the subject wear the accelerometer for an additional period of time to provide ‘valid’ data.

Data reduction criteria for the accelerometer data were similar to what has been used previously (12, 18). In short, the accelerometer was determined not to have been worn for periods defined as ≥30 continuous minutes of zero activity counts. Daily wear time was calculated by subtracting this ‘non-wear time’ from total minutes possible in a day (1440 min). A ‘valid’ day was defined as a day in which the accelerometer was worn for ≥10 hours. Data from ‘partial days’ (i.e., first and last days, as well as days with <10 hours of wear time) were excluded from the analyses. To be included in the following analyses, participants needed to have ≥4 ‘valid’ days, independent of whether they were weekend days or weekdays given previous reports which found that the type of day (e.g., weekend vs. non-weekend) did not influence PA patterns among Look AHEAD participants (18). Further, participants were included in the analyses if they had valid data at baseline, Year 1 or Year 4.

Physical activity intensity was computed for each minute that the device was worn, and was expressed in metabolic equivalents (METs). Minute-by-minute MET values were calculated by dividing the estimated kcal/min by the estimated resting energy expenditure (kcal/min) that was specific to each participant and provided by the proprietary StayHealthy software that accompanied the accelerometer. The following outcome variables were computed: 1) Bout-related MVPA minutes were determined by taking any minute of activity that was ≥3 METs and ≥10 minutes in duration, allowing for a 1-minute interruption in MVPA (i.e., one minute <3.0 METs). The sum of these bout-related MVPA minutes was calculated across all ‘valid days’ and divided by the number of ‘valid days’ to get average minutes/day. This daily average was then multiplied by seven and data are presented as minutes/week of bout-related MVPA, 2) MET-min/week was calculated by summing the MET values for each minute identified as part of an MVPA bout, and 3) METs/bout, which is a measure of the intensity of the MVPA bouts, was calculated by adding the MET values for each minute spent engaging in an MVPA bout and dividing by the number of bouts. METs/bout was only calculated for participants with ≥1 MVPA bout.

Analyses were conducted to examine whether ILI and DSE differed on any of these aforementioned PA variables and to examine whether the percentage of participants achieving the PA intervention goal differed by treatment arm. Further, individual level PA responses to the intervention were examined by stratifying participants into one of four categories at each time point: <50, 50 to <150, 150 to <250, ≥250 min/week. These categories were chosen to determine the proportion of participants who were inactive (<50 min/wk) and inadequately active (50 to <150), as well as those meeting the PA recommendation for improved health (≥150 min/week) and weight maintenance (≥250 min/wk) (5, 20, 28).

Statistical Analyses

Accelerometry related variables of interest by treatment assignment and by study time point, were examined and p-values comparing the two arms were calculated using either t-tests or chi-square tests. Linear mixed models comparing ILI versus DSE were constructed examining bout-related MVPA, MET-min/wk and METs/bout adjusting for accelerometer wear time. Time by treatment interactions were explored. Logistic regression analyses were performed with outcomes being adoption of recommended ≥175 minutes per week of PA at Year 1 and maintaining that recommendation at Year 4. Statistical significance was set at $p<0.05$. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Participants

Of the 5145 participants enrolled in the Look AHEAD Study, 2627 were enrolled at clinical sites participating in the accelerometer sub-study. Only those 2400 participants with 'valid' accelerometer data at baseline, 1 year, or 4 years were included in the analyses: baseline: n=1980, Year 1: n=1460, Year 4: n=1404 (see figure, Appendix 1, Supplemental Digital Content 1, shows flow of participants through study). The percentage of participants with valid data at each time point did not significantly differ between ILI and DSE. Moreover, 80% of the sample had valid data for a minimum of two time points and 46% had data at all three time points.

Descriptive data for the analyzed sample are shown in Table 1. ILI and DSE did not differ on any of the variables examined with the exception of HbA1c, which was 0.1% higher in DSE compared to ILI ($p=0.02$). On average, participants wore the device for 13.0, 12.8, and 12.4 hours/day at baseline, Year 1, and Year 4 respectively, with no differences in wear time between ILI and DSE (p's>0.05). Similarly, the number of 'valid' days (Baseline: 6.1, Year 1: 5.9, Year 2: 5.8 days) did not differ by treatment arm at any time point (p's>0.05).

Mean PA levels

As shown in Table 2, there was a significant group x time interaction effect for bout-related MVPA and MET-min/week (p's<0.001), but not METs per bout. Compared to DSE, ILI engaged in significantly more minutes/week and MET-minutes/week of bout-related MVPA during Years 1 and 4 (p's<0.05), despite there being no difference between treatment arms at baseline. The intensity in which the MVPA bouts were performed (i.e., METs/bout) did not differ between ILI and DSE, but there was a significant time effect such that the intensity at which MVPA bouts were performed decreased over time.

Stratification of participants based upon various PA thresholds

In addition to examining whether ILI and DSE differed in the number of minutes/week spent in bout-related MVPA, we also examined the percentage of participants achieving the Look AHEAD study PA goal of ≥175 minutes/week of bout-related MVPA (Figure 1). Although ILI and DSE did not differ at baseline, almost twice the number of ILI participants engaged in ≥175 min/week at Year 1 and also at Year 4, compared to DSE. Further, of those individuals achieving ≥175 min/week at Year 1, 60.1% and 53.2% of ILI and DSE participants respectively fell below this 175 min/week threshold at baseline (data not shown). This suggests that over half of the participants achieving the ≥175 min/wk goal at Year 1 transitioned into this category (i.e., not achieving goal at baseline), and this transition was more likely to occur in ILI compared to DSE (p<0.0001).

To further examine individual-level PA responses to the intervention, we stratified participants into one of four MVPA categories at baseline, Year 1, and Year 4 (Table 3) and examined the percentage of participants achieving national PA recommendations. While at baseline, there were no differences in the percentage of ILI and DSE participants falling into any of the PA categories (p's>0.29), the percentage of participants achieving <50 minutes/week of bout-related MVPA was significantly greater in DSE, compared to ILI, at both Years 1 and 4 (p's<0.001). Further, significantly more ILI participants achieved 50-150, 150-250 and ≥250 min/week of bout-related MVPA compared to DSE at Year 1 (p's<0.03), while at Year 4, the percentage of ILI participants was only significantly greater than DSE for the ≥250 minute/week category (p<0.001), with a trend towards significance observed for the 150-250 min/week category (p=0.08). Overall, 33.7% and 21.4% of ILI participants (compared to 19.4% and 14.0% in DSE) achieved or exceeded the national PA threshold for improved health (i.e., ≥150 min/week) at Years 1 and 4 respectively. Further, 20.2% and 11.3% of ILI participants (compared to 9.5% vs. 6.3% of DSE participants) met ACSM's PA threshold for weight control (i.e., ≥250 min/week) at Years 1 and 4 respectively.

Using the 4 MVPA categories established previously (see Table 3), Table 4 examines whether these 4 groups differ from one another in MET-minutes/week or METs per bout within any given treatment arm at any given assessment time point. Findings reveal that as duration of MVPA increased, the intensity at which the exercise bouts were performed (i.e., METs/bout) also increased, such that those individuals engaging in the greatest amount of bout-related MVPA (i.e., ≥ 250 min/wk) were also performing these MVPA bouts at a higher intensity compared to those engaging in fewer minutes of MVPA (e.g., <50 min/week). Also of note is that ILI and DSE participants falling into the ≥250 minute/week category were engaging in very high levels of bout-related MVPA (range = 427.4 – 520.8 min/week) which was equivalent to 2511 to 3025 MET-minutes/week.

Predictors of adoption and maintenance of PA

Finally, we examined predictors of adoption (i.e., ≥175 min/week of bout-related MVPA at Year 1) and maintenance (i.e., ≥175 min/week of bout-related MVPA at Years 1 *and* 4) of PA over the 4-year treatment period, using the Look AHEAD PA goal (Table 5). Adoption of the MVPA goal at Year 1 was more likely in those randomized to ILI, in those who were younger, had a lower BMI, had higher baseline PA levels, were white, and were male. While 18.3% and 10.0% of ILI and DSE participants respectively engaged in ≥175 min/week at Year 4 (Figure 1), 40.7% (n=79) and 33% (n=34) of those ILI and DSE participants who achieved ≥175 min/week at Year 1 also maintained ≥175 minutes/week by Year 4 (ILI vs. DSE: p=0.19). Compared to those who did not maintain this magnitude of PA, maintainers were more likely to have no prior history of cardiovascular disease, have a lower BMI, were insulin users, and had higher baseline PA levels.

Discussion

This study examined the effect of a behavioral weight loss intervention on objectively-assessed PA at 1 and 4 years of follow-up in older adults with type 2 diabetes. Participants randomized to ILI engaged in significantly more bout-related MVPA at 1 and 4 years compared to DSE. Further, ILI participants were more likely to adopt and maintain the study PA goal of ≥175 minutes/week of bout-related MVPA; the percentage of ILI participants achieving this PA goal was almost twice that of DSE at Years 1 and 4. These findings suggest that an intensive lifestyle intervention can result in both short- and long-term improvements in PA in this population.

Despite the fact that the most intensive portion of the intervention occurred within the first year of treatment, it is promising that ILI participants as a whole continued to engage in 29 additional minutes/week of MVPA (162 MET-min/week) at Year 4 compared to DSE. Further, data from the Movement and Memory ancillary study of Look AHEAD, which collected objective PA data on a different subset of study participants at Year 8, reported that ILI continued to engage in 109 more MET-min/week of bout-related MVPA compared to DSE (11). These findings may be particularly relevant given that this was an older, aging population, and indicate that not only did ILI attenuate the decline observed in PA among DSE over the 4-year period, but the intervention actually increased PA above baseline levels. Although modest, these changes in PA could have significant clinical implications for older adults, particularly given that lower PA is associated with greater declines in cognitive (1, 34) and physical functioning (17) in aging populations. This is currently being examined as part of an ancillary study of the Look AHEAD Trial. Further, even PA levels less than what is recommended can have positive effects on mental health, all-cause mortality, and weight control (9, 21, 32).

The current study advances previous research by including participants of varying activity levels at study entry, and not just those engaging in little PA at baseline. On average, Look AHEAD participants were engaging in approximately 90 minutes/week of bout-related MVPA at baseline and approximately 20% were achieving ≥150 minutes/week of MVPA (mean MVPA for these participants was 256.1±180.5 min/wk). Although 90 min/week is well below the national PA recommendation for improved health (i.e., ≥150 min/week), this is significantly greater than accelerometry reports among NHANES participants of a similar age who averaged approximately 40 minutes/week of bout-related MVPA, with 6.3-8.5% engaging in ≥150 min/week of bout-related MVPA (27-28). Although previous research suggests that individuals with Type 2 diabetes engage in less PA compared to their non-diabetic counterparts (19), our data suggest that the Look AHEAD study participants may have been slightly more active than the typical older adult with type 2 diabetes. However this may be partially explained by the fact that all Look AHEAD participants had to pass a maximal exercise test at baseline and individuals with a fitness level of <4 METs were excluded from the study. Further, differences in the accelerometer or data reduction methods used by Look AHEAD and NHANES may also account for these observed differences in bout-related MVPA (6).

As noted above, there was a wide range of MVPA levels observed among Look AHEAD participants at baseline. This variability provided a unique opportunity to examine the influence of baseline PA on the adoption and maintenance of PA over time. Findings from this study suggest that those with higher levels of MVPA at baseline were more likely to achieve and maintain the ≥175 min/week MVPA goal at Years 1 and 4. While these findings may be somewhat intuitive given the use of an absolute cut-point (i.e., ≥175 minutes/week) to define adoption of PA at Year 1, our data suggest that approximately 60% of ILI participants achieving ≥175 min/week at Year 1 fell below this threshold at baseline, thus transitioning into this category; only 40% of ILI participants who achieved ≥175 min/week at Year 1 were already engaging in this level of PA before the intervention. Thus the Look AHEAD ILI effectively increased MVPA among a significant proportion of individuals with low MVPA at baseline. In fact, a significant number of ILI participants were engaging in extremely high levels of PA at follow-up. For example, at Year 1, 20% of ILI participants achieved ≥250 min/week and on average were engaging in 464 min/week of bout-related MVPA (2773 MET-min/week) and performing these bouts at an intensity of 6 METs, which is at the lower end of vigorous-intensity PA range. Although a smaller percentage of ILI participants achieved ≥250 min/week at Year 4 (11.3%), the average PA duration and intensity of those achieving the goal were just as high as Year 1. Thus, this suggests that many older individuals with type 2 diabetes are capable of engaging in high levels of MVPA, performed at a vigorous intensity.

To our knowledge, this is the first study to examine predictors of long-term (e.g., 4 years) PA maintenance using objective PA measures within the context of a lifestyle intervention for older adults. Findings reveal that those most likely to achieve and maintain the study PA goal at Years 1 and 4 were those with a lower BMI, no history of cardiovascular disease, and higher baseline levels of PA. Given the unique characteristics of this study, it is difficult to compare the current findings to previous trials due to differences in subject characteristics (older adults with preexisting disease vs. general population), PA measurement (objective vs. self-report), and study focus (PA maintenance vs. long-term PA adoption) and design (longitudinal vs. cross-sectional). Nonetheless, studies most similar to the current study have also reported that lower BMI (2, 33) and higher baseline PA (2) were associated with greater long-term PA adoption or maintenance. While the current study found no effect of age, gender, or ethnicity on PA maintenance, similar studies have reported significant, yet mixed results for these demographic variables (2, 25, 33). Further, in a prospective study of older adults that examined PA maintenance, no sociodemographic factors were found to predict PA maintenance at year 5 (17). Given the limited number of studies and equivocal findings, there is a clear need for additional research specifically focused on identifying demographic, behavioral, and psychosocial characteristics of individuals successful at sustaining high PA levels in order to inform development of more effectively tailored interventions to optimize PA maintenance.

Finally, it should be noted that although the intervention was effective at increasing PA in ILI as a whole, approximately 65% and 80% of ILI participants failed to meet the national PA recommendation (i.e., ≥150 min/week) at Years 1 and 4 respectively. Further, among those not achieving adequate levels of MVPA at Years 1 and 4, approximately half of those participants engaged in zero bouts of MVPA that were ≥10 minutes in duration. This suggests that not only do a large percentage of individuals fail to adopt PA as a result of a lifestyle intervention, but many remain completely inactive, not engaging in any MVPA. Individuals least likely to achieve the study PA goal at Year 1 were older, had a higher BMI, were of an ethnic minority group, and were female. Thus, future interventions should focus on developing new strategies to assist those least likely to adopt PA as part of a behavioral weight loss intervention.

The strengths of this study are a large, diverse sample size, use of an objective measure of PA, and a long-term (4-year) follow-up period. Further, given that this was an older, aging population, this study is additionally strengthened by the use of a control group, which allowed for the examination of how PA changed over time without an intensive lifestyle intervention. However despite the numerous strengths, this study was not without limitations. First, 70-83% of eligible participants had valid accelerometer data at any given time point, and thus it is unclear how data from missing participants may have impacted the findings. However it should be noted that the percentage of participants with valid accelerometer data did not differ between ILI and DSE. In addition, a global limitation with accelerometry is that accelerometers may not be able to detect all forms of MVPA that older adults engage in. Further, given that baseline PA levels were much higher than those reported among the general population, it is possible that individuals who signed up for this study were more motivated than their similar age counterparts with type 2 diabetes; thus it is possible that the modest decline in MVPA observed among DSE participants at Year 4, may have been even greater, had the DSE participants not been enrolled in this study. Finally, the exercise prescription was delivered within the context of a weight loss intervention and thus it is unclear how this may have affected exercise behavior.

In conclusion, when compared to a control condition, individuals with type 2 diabetes who were randomized to an intensive lifestyle intervention engaged in significantly higher levels of bout-related MVPA at 1 and 4 years. Further, those randomized to ILI were over two times as likely to achieve the study PA goal of ≥175 min/week of bout-related MVPA at Year 1, and 1.5 times as likely to maintain that PA goal between Years 1 and 4, when compared to DSE. However, despite these significant differences between groups, a large proportion of individuals in both treatment arms did not engage in any bout-related MVPA when assessed at 1 and 4 years. This is of concern given the importance of PA for both individuals with diabetes, as well as for older adults. Future studies should examine and develop innovative strategies to address the barriers to adoption and maintenance in order to increase PA among a larger proportion of individuals in this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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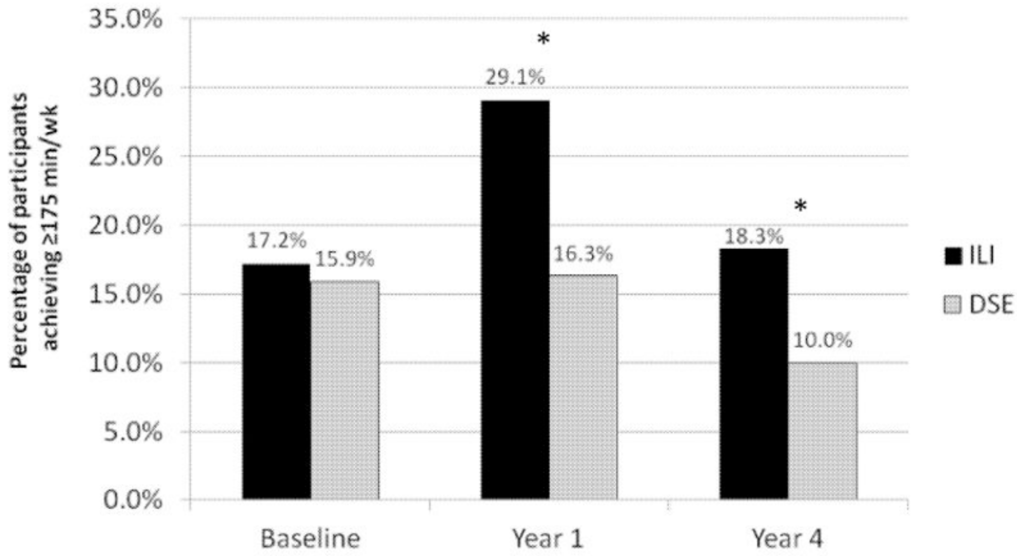

Figure 1. Percentage of participants meeting or exceeding the study physical activity goal of 175 min/week of bout-related moderate-to-vigorous intensity physical activity

Legend: * Indicates that groups were significantly different from one another (p<0.001)

Table 1

Baseline characteristics of the Look AHEAD Accelerometry substudy participants

	Overall (n = 2400)	DSE (n = 1201)	ILI (n = 1199)	p-value*
Age	59.3 (6.85)	59.5 (6.79)	59.1 (6.92)	0.25
Sex (% female)	1340 (55.8%)	684 (57.0%)	656 (54.7%)	0.27
Ethnicity (%)				0.81
African American	471 (19.6%)	240 (20.0%)	231 (19.3%)	
Native American/Alaskan Native	18 (0.75%)	7 (0.58%)	11 (0.92%)	
Asian/Pacific Islander	17 (0.71%)	7 (0.58%)	10 (0.83%)	
Hispanic/Latino	121 (5.04%)	65 (5.41%)	56 (4.67%)	
Non-Hispanic White	1717 (71.6%)	855 (71.2%)	862 (72.0%)	
Other/multiple	55 (2.29%)	27 (2.25%)	28 (2.34%)	
BMI	36.1 (5.9)	36.1 (5.7)	36.1 (6.0)	0.92
Weight (kg)	102.3 (19.0)	102.1 (18.4)	102.5 (19.5)	0.59
Waist circumference (cm)	115.0 (14.5)	114.8 (13.9)	115.2 (15.0)	0.53
HbA1c (%)	7.2 (1.1)	7.3 (1.2)	7.2 (1.1)	0.02
Duration of diabetes (years)	6.9 (6.5)	6.9 (6.3)	6.8 (6.7)	0.83
Insulin use (% using)	428 (17.8%)	222 (18.5%)	206 (17.2%)	0.40
History of CVD (%)	364 (15.2%)	175 (14.6%)	189 (15.8%)	0.42
Fitness (max METs)	7.1 (1.9)	7.1 (2.0)	7.1 (1.9)	0.93

ILI=intensive lifestyle intervention; DSE=Diabetes Support and Education;

*p-value for mean/proportional equivalence across groups

Table 2

Bout-related moderate-to-vigorous intensity physical activity stratified by treatment arm and assessment time point

	ILI		DSE		Group	Time	Group × Time
	N	Mean (SE)	N	Mean (SE)			
Bout-related MVPA (min/wk)					<0.0001	<0.0001	<0.0001
Baseline	985	91.3 (6.0)	995	86.0 (6.0)			
Year 1	846	149.7 (6.4)[a]	836	88.1 (6.5)[b]			
Year 4	887	104.3 (6.3)[a]	876	77.0 (6.3)[b]			
MET-min/wk (bout-related MVPA only)					<0.0001	<0.0001	<0.0001
Baseline	985	519.5 (36.1)	995	498.2 (35.9)			
Year 1	846	858.4 (38.8)[a]	836	508.1 (39.0)[b]			
Year 4	887	573.6 (37.9)[a]	876	421.6 (38.2)[b]			
METs per bout (in those with at least 1 bout/week of MVPA)					0.1557	<0.0001	0.6812
Baseline	717	5.3 (0.04)	705	5.3 (0.04)			
Year 1	679	5.4 (0.04)	573	5.3 (0.04)			
Year 4	614	5.1 (0.04)	534	5.0 (0.05)			

ILI=intensive lifestyle intervention; DSE=Diabetes Support and Education ; LSMEANS±SE; Models adjust for accelerometer wear time. Within a given assessment period (e.g., Year 1), values with different superscripts indicate that ILI and DSE are significantly different from one another.

Table 3

Percentage of participants falling into various physical activity categories at each time point

	<50 min/week			50-150 min/week			150-250 min/week			≥250 min/week		
	ILI	**DSE**	**p-value**	**ILI**	**DSE**	**p-value**	**ILI**	**DSE**	**p-value**	**ILI**	**DSE**	**p-value**
Baseline	509 (51.7%)	538 (54.1%)	0.29	268 (27.2%)	259 (26.0%)	0.55	111 (11.3%)	113 (11.4%)	0.95	97 (9.85%)	85 (8.54%)	0.32
Year 1	321 (37.9%)	482 (57.7%)	<0.001	240 (28.4%)	192 (23.0%)	0.01	114 (13.5%)	83 (9.93%)	0.02	171 (20.2%)	79 (9.45%)	<0.001
Year 4	476 (53.7%)	553 (63.1%)	<0.001	221 (24.9%)	200 (22.8%)	0.30	90 (10.1%)	68 (7.76%)	0.08	100 (11.3%)	55 (6.28%)	<0.001

ILI=intensive lifestyle intervention; DSE=Diabetes Support and Education ; N (%); min/week refers to 'bout-related' MVPA

Table 4

Total volume and intensity of bout-related moderate-to-vigorous intensity physical activity (MVPA) stratified by treatment arm and PA category

	ILI			DSE		
	min/wk	**MET-min/wk**	**METs per bout***	**min/wk**	**MET-min/wk**	**METs per bout***
Stratified by baseline PA						
<50 min/wk	12.0 (15.0)	60.1 (79.3)	4.9 (0.9)	11.3 (14.1)	55.4 (73.5)	4.8 (0.9)
50-150 min/wk	88.7 (28.9)	469.0 (181.7)	5.3 (0.9)	91.7 (28.2)	491.3 (180.4)	5.3 (1.0)
150-250 min/wk	191.9 (28.4)	1105.0 (272.9)	5.7 (1.0)	192.8 (29.5)	1112.0 (298.2)	5.7 (1.1)
≥ 250 min/wk	420.5 (283.1)	2511.0 (1439.0)	6.1 (1.2)	427.4 (265.0)	2666.0 (2032.0)	6.1 (1.3)
Stratified by Year 1 PA						
<50 min/wk	13.2 (16.1)	66.3 (84.7)	5.0 (1.1)[a]	11.2 (14.7)	55.4 (78.5)	4.8 (1.0)
50-150 min/wk	93.0 (29.3)	479.7 (181.3)	5.2 (1.1)[a]	92.6 (29.3)	502.7 (201.5)	5.4 (1.2)
150-250 min/wk	191.5 (28.7)	1072.0 (270.8)	5.6 (1.0)	191.3 (26.0)	1113.0 (246.1)	5.8 (1.0)[c]
≥ 250 min/wk	463.9 (289.9)	2773.0 (1674.0)	6.0 (1.1)	431.3 (232.5)	2608.0 (1450.0)	6.1 (1.1)[c]
Stratified by Year 4 PA						
<50 min/wk	11.1 (15.0)	51.8 (72.5)	4.6 (0.9)	9.2 (13.6)	43.7 (67.1)	4.7 (0.9)
50-150 min/wk	94.8 (28.7)	498.7 (194.1)	5.2 (1.0)[b]	92.7 (30.0)	478.6 (192.4)	5.1 (1.0)
150-250 min/wk	193.1 (26.7)	1019.0 (213.9)	5.3 (0.8)[b]	182.7 (26.3)	998.8 (236.5)	5.4 (0.9)[d]
≥ 250 min/wk	476.3 (387.2)	2757.0 (2415)	5.8 (0.9)	520.8 (943.8)	3025 (5693)	5.7 (0.9)[d]

ILI=intensive lifestyle intervention; DSE=Diabetes Support and Education ; The 4 MVPA groups were compared to one another within a particular treatment arm and assessment time point. Values with similar superscripts indicate that the two groups are not significantly different from one another ($p>0.05$; e.g., among ILI participants at Year 1, the METs per bout was similar between those with <50 min/week and those with 50-150 min/week of MVPA). All other comparisons were significantly different from one another ($p<0.05$).

* METs/bout variable only includes those participants with ≥ 1, 10-minute MVPA bout.

Table 5

Predictors of adoption and maintenance of ≥175 min/week of bout-related moderate-to-vigorous intensity physical activity

	Predictors of adoption vs. non-adoption of ≥175 min/week at Year 1		Predictors of maintaining vs. non maintaining ≥175 min/week between Years 1 and 4	
Variable	**Odds Ratio (95% CI)**	**P-value**	**Odds Ratio (95% CI)**	**P-value**
Treatment assignment		<0.001		0.19
ILI	2.340 (1.753, 3.124)		1.491 (0.822, 2.704)	
DSE	1.00		1.00	
Sex		<0.001		0.45
Male	2.460 (1.824, 3.317)		1.260 (0.689, 2.305)	
Female	1.00		1.00	
Age	0.970 (0.949, 0.992)	0.01	1.025 (0.982, 1.069)	0.26
Race/ethnicity		0.01		0.78
Non-white	0.590 (0.401, 0.868)		0.890 (0.387, 2.049)	
White	1.00		1.00	
BMI	0.974 (0.950, 1.000)	0.05	0.930 (0.878, 0.984)	0.01
Prior CVD		0.48		0.02
No	1.155 (0.772, 1.728)		2.982 (1.151, 7.723)	
Yes	1.00		1.00	
Insulin Use		0.23		0.01
No	1.283 (0.857, 1.923)		0.346 (0.150, 0.797)	
Yes	1.00		1.00	
Baseline bout-related MVPA	1.006 (1.005, 1.007)	<0.001	1.002 (1.001, 1.004)	0.01
Change in bout-related MVPA from Baseline to Y1	Not included in model		1.000 (0.999, 1.001)	0.74

ILI=intensive lifestyle intervention; DSE=Diabetes Support and Education; MVPA=moderate-to-vigorous intensity physical activity