Objective Assessed Physical Activity and Weight Loss Maintenance among Individuals Enrolled in a Lifestyle Intervention

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Objective: To examine the relationship between objectively assessed moderate-to-vigorous intensity physical activity (MVPA) and 4-year weight loss (WL) and WL maintenance among individuals with diabetes enrolled in the Look AHEAD trial.

Methods: MVPA was measured in a subgroup of lifestyle intervention participants with accelerometer data at baseline and at 1 and 4 years (n = 553; age: 59.7 ± 6.8 y; BMI: 35.5 ± 5.9 kg/m²). Minutes per week of bout-related MVPA were calculated (≥ 3 metabolic equivalents, ≥ 10-min bouts), and adherence to the national physical activity (PA) recommendation for WL maintenance (≥ 250 min/wk) was assessed.

Results: Independent of 1-year WL, 4-year MVPA (β = 0.0001, SE = 0.001, P = 0.50), but not 1-year MVPA (β = −0.0003, SE = 0.002, P = 0.006), was significantly associated with 4-year WL. Compared with “nonmaintainers” (>10% WL at year 1, but <10% at year 4; n = 132), WL maintainers (≥10% WL at years 1 and 4; n = 103) had higher MVPA at year 1 (253.4 ± 251.8 vs. 163.9 ± 158.2 min/wk, P = 0.002) and year 4 (155.3 ± 180.6 vs. 111.4 ± 154.5 min/wk, P = 0.046). Although 38.8% and 22.3% of WL maintainers engaged in ≥250 min/wk at years 1 and 4, respectively, many engaged in <150 min/wk (year 1: 41%, year 4: 61%).

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Introduction

Physical activity (PA) has been shown to have a modest effect on initial weight loss (WL); however, PA appears to play a more prominent role in WL maintenance (1-4). The American College of Sports Medicine (ACSM) recommends that adults participate in ≥ 150 min/wk of moderate-to-vigorous intensity physical activity (MVPA) to prevent significant weight gain and reduce chronic disease risk. However, for the prevention of weight regain following WL, ≥ 250 min/wk of objectively assessed MVPA is recommended (1). Although these guidelines are evidence based, they were derived largely from studies that have relied on self-reported measures of PA, which are often prone to participant biases, including social desirability influence and imprecise recall (5). Findings from one study confirmed previous self-reported PA findings, which demonstrated that 200 to 300 min/wk of objectively assessed MVPA, accumulated in bouts > 10 minutes, was associated with improved WL at 18 months. However, the proportion of participants meeting the recommended 250 min/wk threshold was not examined (6). Given that stronger associations between objective PA, rather than subjective PA, and various health indicators have been observed (7,8), it is imperative that the role of objectively assessed PA continues to be examined within the context of long-term WL and weight maintenance.

The optimal level of PA needed for long-term WL and weight maintenance is not entirely understood. Although long-term WL is often examined by determining the proportion of participants meeting a clinically significant WL threshold at a distant time point (e.g., ≥ 10% at 18 mo), WL maintenance requires an individual to both achieve and maintain WL ≥ 10% both initially and at follow-up (9,10). Few studies have examined the quantity of objectively measured MVPA required for successful WL maintenance within the context of behavioral WL intervention trials longer than 18 months. In addition, it is unclear whether the level of MVPA needed to maintain WL is similar in older adults, specifically those with diabetes, given that those individuals typically have lower than average levels of MVPA (11,12).

The Look AHEAD trial provides an excellent opportunity to address these questions. Look AHEAD is a multicenter randomized triald examining the effect of an intensive lifestyle intervention (ILI) on the primary and secondary prevention of cardiovascular disease in adults with overweight or obesity and type 2 diabetes. We have previously reported on changes in weight (13) and objectively assessed PA in Look AHEAD (14) and found that those randomly assigned to the ILI arm had significantly greater WL and significantly more MVPA minutes at 1 and 4 years, compared with the diabetes support and education group (DSE; control condition). In addition, the percentage of participants losing and maintaining ≥ 10% WL was far greater in ILI than in DSE. In this paper, we examined the relationships among (1) PA and WL at 1 year (short-term WL), (2) PA and WL at 4 years (long-term WL), and (3) PA and WL maintenance between years 1 and 4. Specifically, we capitalized on the large number of individuals randomly assigned to ILI who achieved ≥ 10% WL at year 1 (n = 235; 43% of sample), and we examined whether there are differences in MVPA between those who maintain and do not maintain this magnitude of WL. In addition, we examined individual-level MVPA data and identified the percentage of WL maintainers who achieved the PA guidelines for weight control (1).

Methods

Participants

Accelerometry data in Look AHEAD were collected at 8 of the 16 sites of this trial (n = 2,622). Full descriptive data for ILI participants (n = 1,309) enrolled in the accelerometer substudy have been reported previously (15). Given that the aim of this paper was to examine changes in PA and WL between years 1 and 4 (i.e., WL maintenance), we studied only ILI participants who had weight and valid accelerometer data (see definition below) at baseline, year 1, and year 4 (n = 573). In addition, participants who underwent bariatric surgery at any time point were excluded (n = 20); thus, the present analyses focus on 553 participants. Participants included in these analyses were similar to the entire accelerometer substudy cohort on all demographic measures, except for BMI, which was lower in the current subgroup of participants (35.5 ± 5.9 kg/m² vs. 36.4 ± 6.0 kg/m²). In short, participants included in these analyses were 59.7 ± 6.8 years of age, 55% female, and 76% Caucasian at baseline. All participants provided written informed consent, and study procedures were approved by each center’s institutional review board.

Outcome measures

Weight change. Body weight was assessed at baseline, year 1, and year 4 by using a digital scale (model BWB-800; Tanita, Willowbrook, Illinois) operated by a staff member masked to the intervention assignment. The change in weight from baseline to 1 year and from baseline to 4 years was calculated.

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data were analyzed to determine bout-related MVPA, which was defined as any activity ≥ 3 METs and ≥ 10 minutes in duration, allowing for a 1-minute interruption in MVPA (i.e., 1 min < 3 METs). MET minutes per week spent in bout-related MVPA were calculated by multiplying the number of MVPA minutes by the mean MET value.

 Treatment conditions

Look AHEAD participants were randomly assigned to an ILI group or to a DSE group, which served as the comparison group. Full descriptions of the ILI and DSE conditions have been provided previously (13,17). The analyses presented focus only on ILI participants.

During months 1 to 6, ILI participants attended three weekly group sessions and one individual counseling session per month, which was reduced to two group sessions and one individual session per month in months 7 to 12. During years 2 to 4, participants had one in-person individual meeting (20-30 min) with their interventionist each month, with a second individual contact by telephone (10-15 min) or email 2 weeks later. In addition, in years 2 to 4, monthly group sessions were offered; in these sessions, participants listened to a presentation on a new topic on lifestyle modification, which included information on food intake, PA, or behavior change.

In year 1, ILI participants were prescribed a calorie goal of 1,200 to 1,800 kcal/d depending on initial body weight, were instructed to consume < 30% of total calories from dietary fat, and were provided with meal replacements. Participants were given a home-based PA regimen designed to gradually increase structured activity to ≥ 175 min/wk within the first 6 months, with a further increase to ≥ 200 min/wk for those who met this goal. Effective behavioral strategies such as regular self-weighting, daily self-monitoring, and stimulus control techniques were discussed. In years 2 to 4, participants continued with individualized calorie goals and were encouraged to continue to exercise for at least 175 min/wk.

Statistical analyses

The changes in PA and weight over the three time points were assessed by using general linear models for continuous variables and \( \chi^2 \) tests for categorical variables. Post hoc comparisons across time points and outcomes utilized a Bonferroni correction. Correlations were computed to examine the relationship between both 1-year PA and the 1-year change in PA with 1-year WL, while also controlling for baseline PA, year 1 accelerometer wear time, and other demographic variables, including age, gender, and race. Exploratory analyses examined the relationship between 1-year or 4-year PA and weight change by stratifying participants into one of four PA categories: < 50, 50 to < 150, 150 to < 250, and ≥ 250 min/wk. A general linear model was used to compare these PA categories on 1-year WL or 4-year WL, and post hoc group comparisons utilized a Bonferroni adjustment. Linear models were used to examine whether 1-year or 4-year PA was most strongly associated with 4-year WL and to determine whether 4-year WL was predominately driven by changes in 1-year WL or PA engagement. Linear models were also used to compare WL maintainers and nonmaintainers on PA at each time point. Exploratory analyses, examining whether the distribution of WL maintainers falling into various PA categories at years 1 and 4 differed from nonmaintainers, were performed by using \( \chi^2 \) analyses. All analyses were performed by using SAS version 9.4 (SAS Institute, Cary, North Carolina), and statistical significance was set at \( P < 0.05 \).

Results

Table 1 presents weight change and PA data at baseline and at 1 and 4 years in these participants. Mean WL was 9.7% at year 1 and 5.0% at year 4. Forty-three percent achieved or exceeded the national PA goal for 150 min/wk. A general linear model was used to compare 1-year or 4-year PA with 1-year WL, while also controlling for baseline PA, year 1 accelerometer wear time, and other demographic variables, including age, gender, and race. Exploratory analyses examined the relationship between 1-year or 4-year PA and weight change by stratifying participants into one of four PA categories: < 50, 50 to < 150, 150 to < 250, and ≥ 250 min/wk.

| TABLE 1 Descriptive PA and body weight data stratified by assessment time point in ILI participants (n = 553) |
|---------------------------------------------------------------|
|                                | Baseline | Year 1       | Year 4       | Overall P value over time |
| PA Accelerometer wear time, h/d                             | 13.1 (12.9 to 13.3) | 12.9 (12.7 to 13.1) | 12.7 (12.4 to 12.9) | 0.05 |
| Bout-related MVPA, min/wk                                     | 98.7 (86.8 to 110.6)a | 161.6 (142.3 to 180.8)b | 110.5 (92.1 to 128.9)a | <0.0001 |
| MET-min/wk                                                    | 564.3 (492.9 to 635.7)a | 924.1 (811.3 to 1,037)b | 613.7 (502.6 to 724.8)a | <0.0001 |
| % Achieving ≥ 150 min/wk of MVPA                             | 122 (22.1)ab | 198 (35.8)b | 128 (23.2)c | <0.0001 |
| % Achieving ≥ 250 min/wk of MVPA                             | 61 (11.0)a | 115 (20.8)b | 68 (12.3)c | <0.0001 |
| Body weight                                                   |                         |                         |                         |
| Weight, kg                                                    | 100.9 (99.3 to 102.5)a | 91.0 (89.5 to 92.5)b | 95.8 (94.2 to 97.4)c | <0.0001 |
| Weight change from baseline (%)                              | −9.7 (−10.2 to −9.1)b | −5.0 (−5.6 to −4.4)b |                         | <0.0001 |
| % Achieving ≥ 5% WL                                          | 421 (76.1)a | 269 (48.6)b |                         | <0.0001 |
| % Achieving ≥ 10% WL                                         | 235 (42.0)a | 129 (23.3)b |                         | <0.0001 |

Values presented as mean (95% CI) or n (%).
Values with different superscripts across columns are significantly different from one another after Bonferroni adjustment.
In our study, we focused on the relationship between physical activity (PA) and weight loss maintenance. We observed that participants engaging in ≥250 min/wk at year 1 and year 4 had greater weight loss (WL) at year 1 than those engaging in <250 min/wk (mean = 11.5% vs. 8.26%, 95% CI: 6.08-10.43, P = 0.001, 95% CI: 3.66-7.44, n = 135). Those engaging in <50 min/wk (mean = 5.80%, 95% CI: 4.02-7.59, n = 290) showed no significant differences between the other PA groups.

We also examined whether 4-year MVPA predicted percent weight change at year 4, independent of 1-year PA or 1-year WL. Findings revealed that 1-year weight change was most strongly associated with the percent weight change at 4 years (β = 0.638, SE = 0.04, 95% CI: 0.56 to 0.71, P < 0.001). However, 4-year MVPA was also a significant predictor of 4-year WL (β = -0.003, SE = 0.001, 95% CI: -0.0001 to -0.006, P = 0.006), whereas 1-year MVPA was not (β = 0.001, SE = 0.001, 95% CI: -0.002 to 0.003, P = 0.50). Translated clinically, these findings suggest that for every additional 1 kg of WL at year 1, 4-year WL was increased by 0.61 kg, and for every additional 30 minutes of MVPA at year 4, 4-year WL increased by 0.12 kg.

**Aim 3: PA and weight maintenance**

Weight maintenance (i.e., weight change from year 1 to year 4) was examined only in those 235 participants achieving ≥10% WL at year 1. Participants were stratified into one of two categories on the basis of their year 1 and year 4 WL: (1) maintain (n = 103): 1-year and 4-year WL ≥10% and (2) nonmaintain (n = 132): 1-year WL ≥10% and 4-year WL <10%. By definition, 4-year WL was significantly greater in maintainers (mean = 15.1%, 95% CI: 14.23-15.98) than in nonmaintainers (mean = 4.0%, 95% CI: 3.27-4.78, P < 0.001). On average, the maintain and nonmaintain groups regained 11% and 72% of their initial WL, respectively, between years 1 and 4.

Table 2 compares the activity levels of maintainers and nonmaintainers. Although baseline MVPA levels did not differ between groups, the maintain WL group engaged in significantly more activity at both year 1 and year 4. Exploratory analyses were conducted to examine whether the distribution of participants falling into the various PA categories differed between WL maintainers and nonmaintainers at year 1 and year 4 (Figure 2). Compared with the nonmaintain group, a greater percentage of maintainers were engaging in ≥250 min/wk at year 1 (38.8% vs. 22.0%, P < 0.05). At year 4, 22.3% of maintainers and 12.9% of nonmaintainers were engaging in ≥250 min/wk (P = 0.06). It is of note that 18% and 40% of those maintaining ≥10% WL between years 1 and 4 were engaging in <50 min/wk of bout-related MVPA at years 1 and 4, respectively.

**TABLE 2 Mean bout-related MVPA at several time points stratified by weight maintenance categories (aim 3)**

|                  | Maintain WL (n = 103) | Nonmaintain WL (n = 132) | P value for difference between groups |
|------------------|-----------------------|--------------------------|--------------------------------------|
| Baseline         | 112.12 (85.58 to 138.66) | 129.49 (95.61 to 163.37) | 0.425 |
| Year 1           | 253.42 (204.22 to 302.62) | 163.86 (136.62 to 191.10) | 0.002 |
| Year 4           | 155.34 (120.04 to 190.64) | 111.40 (84.79 to 138.01) | 0.046 |
| Year 1 to year 4 change | -98.08 (-141.86 to -54.30) | -52.46 (-80.83 to -24.09) | 0.073 |

Values presented as mean (95% CI).
In this cohort of older adults with type 2 diabetes, higher levels of objectively assessed MVPA were associated with improved WL maintenance. WL maintainers averaged approximately 250 min/wk of bout-related MVPA at year 1 and 150 min/wk at year 4. Although WL maintainers were more likely to engage in ≥ 250 min/wk of MVPA than nonmaintainers, there was large variability, with 40% to 60% of individuals engaging in < 150 min/wk at year 1 or year 4. This suggests that there may be more than one pathway to successful WL maintenance in this population and that ≥ 250 min/wk of MVPA may not be necessary.

In addition to WL maintenance, this study also assessed the relationship between PA and initial WL. The current findings confirm and extend previous reports indicating that higher bout-related MVPA at year 1 was associated with greater 1-year WL (18,19). Approximately one-third of study participants engaged in ≥ 150 min/wk of MVPA at year 1. These individuals lost an additional 4% of initial body weight, compared with those engaging in <150 min/wk. This 4% difference in observed WL is similar to that of a previous study in which behavioral WL participants engaging in ≥150 min/wk of self-reported PA lost approximately 9% of initial body weight at year 1, whereas those engaging in <150 min/wk only achieved a 4% WL (20). However, the latter study (20) reported that those engaging in ≥ 200 min/wk at year 1 had even greater WL (approximately 14% of initial body weight) than those engaging in ≥ 150 min/wk. In the current study, this was not the case; engagement in ≥ 250 min/wk had no additional effect on WL, compared to 150-250 min/wk. Thus, in older adults with type 2 diabetes, meeting the national public health recommendation of ≥ 150 min/wk of bout-related MVPA within the context of a comprehensive weight management program may be sufficient for initial WL success.

A second aim of this study was to examine the relationship between PA and long-term WL. It is generally accepted that high PA is important for long-term weight control (1); however, few behavioral WL interventions have been >24 months in duration, making it difficult to assess this long-term relationship. Previously, Tate et al. (21) reported that participants engaging in approximately 300 min/wk of MVPA at 30 months lost 12 kg, compared to a 1-kg WL observed among those engaging in <300 min/wk. In the Diabetes

Discussion

In this cohort of older adults with type 2 diabetes, higher levels of objectively assessed MVPA were associated with improved WL maintenance. WL maintainers averaged approximately 250 min/wk of bout-related MVPA at year 1 and 150 min/wk at year 4. Although WL maintainers were more likely to engage in ≥ 250 min/wk of MVPA than nonmaintainers, there was large variability, with 40% to 60% of individuals engaging in < 150 min/wk at year 1 or year 4. This suggests that there may be more than one pathway to successful WL maintenance in this population and that ≥ 250 min/wk of MVPA may not be necessary.

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Prevention Program, the odds of achieving a 7% WL goal at the end of the intervention (~3.2 y) was 4.11 times greater in those who achieved the PA goal of ≥ 150 min/wk than in those not achieving the goal (22). Although these data suggest the potential importance of PA for long-term weight control, these studies utilized self-reported PA measures, had shorter study durations, and had smaller sample sizes than the Look AHEAD Trial. In the current study, we report that 4-year PA (not 1-year PA) was the strongest predictor of 4-year weight change, and participants achieving ≥ 250 min/wk of MVPA at year 4 lost 8.2% of initial body weight, which was significantly greater than those engaging in any of the lower levels of activity, all of whom lost about 5.7% of body weight. Although these data speak to the importance of PA for weight maintenance, it is difficult to examine this. Finally, given that this was an older population with more comorbidities, it is possible that using a 3-MET threshold may have failed to capture all activity completed for the purpose of exercise or that some individuals lost weight or decreased PA over time as a result of illness, thus reducing the association between MVPA and WL maintenance. Therefore, the generalizability of these findings may be limited to older adults with type 2 diabetes.

This study had numerous strengths, including the objective measurement of PA, long-term follow-up data, and a large sample size. However, it is not without limitations. All analyses were post hoc comparisons, examining the association between PA and weight change. In addition, the direction of this relationship could not be determined; it is unclear whether WL led to increased PA or whether increased PA resulted in additional WL. Finally, although individuals included in these analyses were demographically similar to those without valid accelerometer data at all three time points, it is possible that these subgroups of individuals differed on other unmeasured parameters, thereby limiting the generalizability of these findings to other populations.

Conclusion

In summary, these findings confirm previous reports regarding the importance of PA for weight control, with higher levels of PA associated with greater initial WL, long-term WL, and weight maintenance. However, within an older population with type 2 diabetes, our data suggest that many individuals are able to achieve and maintain clinically significant long-term WL while engaging in less MVPA than is recommended for WL maintenance. Future studies should examine how those who maintain WL with high PA differ in other weight control behaviors (e.g., dietary intake) or cardiometabolic risk profiles from those maintaining clinically significant WL with less PA.

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