Effect of a Lifestyle Intervention on Change in Cardiorespiratory Fitness in Adults with Type 2 Diabetes: Results from the Look AHEAD Study

John M. Jakicic, Ph.D. [writing group Chair], Sarah A. Jaramillo, MS, Ashok Balasubramanyam, MD, Barbara Bancroft, RN, MS, Jeffery M. Curtis, MD, Anne Mathews, Ph.D., Mark Pereira, Ph.D., Judith G. Regensteiner, Ph.D., and Paul M. Ribisl, Ph.D.

Abstract

**Objective**—To examine the effect of an intensive lifestyle weight loss intervention (ILI) compared to diabetes support and education (DSE) on changes in fitness and physical activity in the Look AHEAD trial.

**Design**—Randomized clinical trial to compare a lifestyle intervention for weight loss with a diabetes support and education condition in individuals with type 2 diabetes.

**Subjects**—Data from 4,376 overweight or obese adults with type 2 diabetes (age = 58.7±6.8 years, BMI = 35.8±5.8 kg/m²) who completed one-year of the Look AHEAD trial and had available fitness data were analyzed.

**Intervention**—Subjects were randomly assigned to DSE or ILI. DSE received standard-care plus 3 education sessions over the one-year period. ILI included individual and group contact throughout the year, restriction in energy intake, and 175 min/wk of prescribed physical activity.

**Measurements**—Fitness was assessed using a submaximal graded exercise test. Physical activity was assessed via questionnaire in a subset of 2,221 subjects.

**Results**—Change in fitness was statistically greater in ILI vs. DSE after adjustment for baseline fitness (20.9% vs. 5.7%) (p<0.0001). Multivariate analysis showed that change in fitness was greater in overweight vs. obese Class II and III (p<0.05). Physical activity increased by 892±1694 kcal/wk in ILI vs. 108±1254 kcal/wk in DSE (p<0.01). Changes in fitness (r=0.41) and physical activity (r=0.42) were significantly correlated with weight loss (p<0.0001).

**Conclusions**—The ILI was effective in increasing physical activity and improving cardiorespiratory fitness in overweight and obese individuals with type 2 diabetes. This effect may add to weight loss in improving metabolic control in patients in lifestyle intervention programs.

**Keywords**

fitness; diabetes; obesity; physical activity; exercise
INTRODUCTION

Data from the 2003–2004 National Health and Nutrition Examination Survey indicate that more than 65 percent of adults in the United States are overweight (BMI: 25.0–29.9 kg/m\(^2\)) or obese (BMI \(\geq \)30 kg/m\(^2\))\(^1\). Overweight and obesity have been linked to numerous chronic diseases including cardiovascular disease, diabetes, several forms of cancer, and musculoskeletal problems \(^2, 3\). This has resulted in obesity-related conditions accounting for approximately 7 percent of total health care costs in the United States, and it is estimated that the direct and indirect cost of obesity is in excess of $117 billion annually \(^4\).

The prevalence of type 2 diabetes is approaching 9 percent of the adult population in the United States, with excess body weight contributing to the current type 2 diabetes epidemic \(^5\). Physical inactivity and low levels of fitness have been shown to contribute to the onset of type 2 diabetes as well \(^6, 7\). Moreover, increased physical activity is considered to be important for the management of type 2 diabetes because it may assist with weight loss and impact insulin resistance and the management of blood glucose \(^8\). Finally, using data from a longitudinal prospective non-intervention study, Church et al. \(^9\) reported that a low level of fitness was associated with an increase in cardiovascular disease (CVD) events in individuals with type 2 diabetes. However, data from randomized clinical trials confirming this finding are lacking.

The Look AHEAD Study is a multi-center clinical trial examining the effect of weight loss and fitness on CVD endpoints in individuals with type 2 diabetes. An important component of the Look AHEAD Study is that objective measures of fitness are obtained on approximately 5,000 individuals randomized to participate in this study, providing a unique opportunity to examine the changes in fitness that can be achieved with an intensive lifestyle intervention. The findings reported herein expand on the one-year outcomes from the Look AHEAD Study that have recently been reported \(^10\), and focus primarily on describing the observed changes in fitness and physical activity, along with demographic characteristics that appear to contribute to changes in fitness.

METHODS

Subjects

A detailed description of the baseline characteristics of subjects in the Look AHEAD Study have previously been published \(^11\). For the purpose of this analysis, data from 4376 individuals who completed the assessment of fitness at baseline and 1 year were available. This represents 85.1% of the subjects recruited and randomized into the Look AHEAD Study. Of the 4376 included in this analysis, 59% were female and 36% were non-Caucasian. At baseline, subjects were 58.7\(\pm\)6.8 years of age with a BMI of 35.8\(\pm\)5.8 kg/m\(^2\). All subjects were diagnosed with type 2 diabetes mellitus, with mean duration of diabetes of 6.7\(\pm\)4.5 years, and HbA1c level of 7.3\(\pm\)1.2%. Descriptive data are presented in Table 1.
Intervention

Intensive Lifestyle Intervention (ILI)—Specific details of the lifestyle intervention implemented in the Look AHEAD Study have been published previously 11, 12. Briefly, for month 1–6 of the intervention participants attended weekly on-site treatment sessions that included group sessions and one individual meeting with their Lifestyle Counselor during each month. During months 7–12, participants attended two group meetings a month, one individual session, and one motivational campaign to promote adherence to the recommended weight loss behaviors. The focus of the group and individual intervention sessions was to implement behavioral strategies related to eating and physical activity with the goal of achieving and maintaining weight loss. Participants in the ILI group continued to receive their general medical care and treatment for their diabetes from their personal physician. However, the intervention sites were permitted to make temporary reductions in medicines that could lead to hypoglycemia during periods of intensive weight loss intervention based on a standardized treatment protocol aimed at avoiding hypoglycemia.

Dietary Intervention: Participants were instructed to reduce their energy and dietary fat intake. Energy intake was prescribed at 1200–1800 kcal/d depending on body weight. Dietary fat intake was prescribed at < 30% of total energy intake, with < 10% consumed as saturated fat. During the first 16 weeks, a portion-controlled meal plan was prescribed which included replacement of two meals per day (typically breakfast and lunch) with a prepackaged liquid shake or snack bar, a conventional evening meal, and consumption of fruits and vegetables. The liquid shake and snack bars were provided at no cost to participants. After 16 weeks, the meal replacements provided to participants were reduced to one shake and one snack bar per day. Individuals who declined the use of the meal replacement options were provided detailed meal plans of conventional foods to consume for their daily meals.

Physical Activity Intervention: Participants were instructed initially to increase their physical activity to at least 50 min/wk, progressing to at least 175 min/wk by week 26, with the intensity being moderate-to-vigorous (similar to brisk walking). Physical activity bouts of ≥10 minutes were counted toward the weekly activity goal, with resistance exercise permitted to count up to 25% of the weekly goal. The physical activity intervention relied primarily on home-based forms of activity. Additionally, participants were encouraged to increase lifestyle forms of physical activity (using stairs rather than elevators, walking rather than riding, and reducing use of labor saving devices), and a pedometer was provided to each participant at week 7 to monitor daily steps.

Special Treatment Components: The ILI included a toolbox of behavioral strategies that could be implemented for participants who were having difficulty adhering to the diet and exercise recommendations, or who did not meet minimal weight loss goals. Moreover, pharmacotherapy (Orlistat) was made available for individuals who failed to achieve minimal weight loss goals within the initial 6 months of the intervention, with 519 subjects started on Orlistat prior to their 1-year assessment. Details of the behavioral toolbox and pharmacotherapy options have previously been described in detail 12.
Diabetes Support and Education Intervention (DSE)—The DSE intervention has previously been described in detail. Individuals randomly assigned to the DSE intervention did not receive the comprehensive components of a weight loss intervention as described above for ILI. Rather, DSE participants received general recommendations related to healthful eating and physical activity, and information related to safety of implementation of these recommendations for an individual with type 2 diabetes. Participants attended an initial pre-randomization diabetes education session and were invited to attend 3 additional group sessions, standardized across sites, during the first year that addressed topics related to diet, physical activity and social support. However, specific strategies to change diet or physical activity were not provided to DSE participants. Participants in the DSE group continued to received their general medical care and treatment for their diabetes from their personal physician.

Assessments

Demographic Characteristics—Age, gender, ethnicity, and duration of diabetes were assessed via questionnaire at baseline. HbA1c was assessed from a fasting blood sample by previously published standard methods at a central laboratory.

Height, Weight, and Body Mass Index (BMI) and Waist Circumference—The standardized methods used to measure height, weight, BMI and waist circumference have been described previously.

Cardiorespiratory Fitness—A graded exercise treadmill test was used to assess cardiorespiratory fitness at baseline and following 1-year. Cardiorespiratory fitness was defined as the estimated MET level based on the treadmill work load (i.e., speed and grade) using the criteria explained in detail below of attaining 80% of maximal heart rate for participants not taking a beta-blocker or the criteria of attaining a rating of 16 on the RPE scale. Change in cardiorespiratory fitness was defined as the difference in estimated submaximal METs attained at 1-year and the submaximal METs attained at baseline using the same termination criteria of attaining either 80% of maximal heart rate or attaining a rating of 16 on the RPE scale.

Assessment procedures involved setting the speed of the treadmill at 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0 mph for the baseline test based on preferred speed of the participant and heart rate response during the first minute of the test, and this speed remained constant throughout the test. The grade of the treadmill was initially set at 0% and increased by 1% at 1-minute intervals throughout the test. Heart rate was assessed at rest, during the last 10 seconds of each exercise stage, and at the point of test termination using a 12-lead ECG. Rating of perceived exertion (RPE) was assessed using the Borg 15-category scale (range is on a scale from 6–20) during the last 15 seconds of each stage and at the point of test termination. Blood pressure was assessed using a manual sphygmomanometer and stethoscope during the last 45 seconds of each even minute stage (e.g., 2 min., 4 min, etc.).

The baseline test was terminated at the point of volitional exhaustion or at the point where ACSM 14 test termination criteria were observed. A baseline test was considered valid if the maximal heart rate was ≥85% of age-predicted maximal heart rate (HR_{Max} = 220 minus age).
if the participant was not taking a beta-adrenergic blocking medication (beta-blocker). If the participant was taking a beta blocking medication, the baseline test was considered valid if RPE was ≥18 at the point of termination. Moreover, to be eligible for participation in the Look AHEAD Study the participant need to achieve ≥4 metabolic equivalents (METs) on the baseline graded exercise test, where 1 MET is equal to 3.5 ml/kg/min of oxygen uptake.

The test performed at the 1-year assessment to assess cardiorespiratory fitness was a submaximal test, and this test was performed at the same walking speed as the baseline assessment. This submaximal test was terminated at the time when the participant first achieved or exceeded 80% of age-predicted maximal heart rate (HR_{Max} = 220 minus age) if the participant was not taking a beta-blocker at either the baseline or 1-year assessment period. If the participant was taking a beta-blocker at either the baseline or 1-year assessment then the submaximal test was terminated at the point when the participant first reported achieving or exceeding a rating of 16 on the RPE scale.

**Leisure-Time Physical Activity (LTPA)**—LTPA was assessed on a sub-sample of approximately 50 percent of the participants at baseline and 1-year using the questionnaire developed for the Harvard Alumni Study 15. Data were collected as part of a structured interview. Participants reported their activity over the past week which includes the average flights of stairs (10 steps = 1 flight), number of city blocks walked (1 mile = 12 blocks), and other sport, recreational, or fitness activities. Energy expenditure in LTPA was computed based on previously published standardized scoring procedures 15.

**Statistical Analysis**

Analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC). PROC GLM was used to examine bivariate associations between percent change in fitness at 1-year compared to baseline with baseline characteristics including age, gender, race/ethnicity, insulin use, diabetes medication use, HbA1c, smoking status, metabolic syndrome, BMI, and waist circumference. P-values were tabulated along with least square means, standard error of the mean, and p-values from models adjusting for baseline METs. Variables that were significant in the bivariate analysis, other factors shown to affect baseline fitness in prior Look AHEAD analyses 16, change in body weight and a variety of interaction effects were used to construct multivariate models using PROC GLM. Interactions of gender with each included variable were examined to determine if gender specific multivariate models were necessary. LS means for treatment assignment were computed from the final multivariate model. Spearman correlation coefficients were computed for 1 year weight change compared to 1 year percent fitness change and LTPA along with BMI compared to 1 year percent fitness change and LTPA both overall and by intervention assignment.

**RESULTS**

The baseline demographic characteristics of the study participants are provided in Table 1. Of the 5,145 participants randomized (DSE = 2,575; ILI = 2,570), fitness data were available at both baseline and 1-year on 4,376 participants (85% of the randomized subjects). The reasons for missing fitness data are presented in Figure 1. Of the 159 who missed the 1 year visit, 95 were from DSE and 64 from ILI. Forty seven participants did not
complete the test due to medical reasons, with 35 from DSE and 12 from ILI. When compared to those who did not provide fitness data at one year (N=769), individuals with fitness data at one year (N=4376) had a higher baseline fitness level (6.8±1.9 METs vs. 7.3±2.0 METs), achieved a higher heart rate during fitness testing (145±19 bpm vs. 149±17 bpm), and a higher percent of age-predicted maximal heart rate (90.4±10.5% vs. 92.7±9.9%) (all p<0.0001). There was no significant difference in maximal heart rate achieved during the baseline test between DSE (147.7±17.4 bpm) and ILI (149.5±17.4 bpm) for subjects used to compare changes in fitness at 1-year (N=4376).

For individuals completing the assessment of fitness at both baseline and 1 year, weight loss was significantly greater in ILI (8.8±8.1 kg, 8.7±7.7%) versus DSE (0.8±4.9 kg, 1.0±4.7%) (p<0.0001). These results are similar to the weight loss difference at 1 year in the entire cohort (8.6±6.9% and 0.7±4.8 %, for ILS and DSE, respectively).

Change in Fitness

**Bivariate Analyses**—The comparison for change in fitness between DSE and ILI are presented in Figure 2. Data are presented as the percent change in fitness at 1-year compared to baseline. Change in fitness adjusted for baseline fitness was significantly greater in ILI compared to DSE (p<0.0001) (see Figure 2). Significant differences remained between DSE and ILI when analyzed separately for males and females (see Figure 2).

Data were analyzed to determine the influence of the test termination criteria on the observed changes in fitness. Examination of data for participants who were not taking medication (N=3329) that would affect heart rate revealed a significant improvement in unadjusted fitness in ILI (22.2±30.4%, N=1687) compared to DSE (6.6±22.5%, N=1642) (p<0.0001). A similar pattern of results was observed for analysis of fitness data for which the RPE termination criteria were used (N=1047) for ILI (16.7±24.2%, N=557) and DSE (3.3±20.1%, N=490)) (p<0.001). Thus, the use of a beta blocker did not attenuate the difference for change in fitness between ILI and DSE.

Bivariate analyses adjusting for baseline fitness showed that individuals with a smaller waist circumference, younger age, being male, or not having a prior history of CVD resulted in significantly greater improvements in fitness. There was a trend for greater improvement in fitness individuals with a lower BMI (p=0.0628). Moreover, 13 there was a significant ethnicity effect, with African American/Black or American Indian/Native American/Alaskan Native having a lower change in fitness compared to other race categories. There was greater fitness improvements in individuals taking fewer diabetes medication, not taking insulin, and having a lower HbA1c.

**Multivariate Analysis**—A multivariate analysis was performed to examine factors that significantly contributed to the change in fitness observed in this study. Variables examined in the multivariate model included the factors examined in the bivariate analyses described above (treatment group assignment, BMI, waist circumference, age, gender, race, smoking status, presence of metabolic syndrome, CVD history, use of insulin, type of diabetes medication use, HbA1c level), other factors shown to affect baseline fitness in prior Look
AHEAD analyses 16, change in weight, and a variety of interaction effects. These variables are listed in Table 3.

The results showed after adjustment for the significant variables within the multivariate analysis, percent fitness change for ILI was 5.06 greater than the fitness change for DSE. Higher baseline METs was associated with lower percent fitness change with the decline more prominent in females than males as demonstrated by the significant baseline METs by gender interaction. Change in fitness was lower in individuals with higher levels of baseline BMI, with Obese Class II and III categories resulting in significantly lower improvement in fitness compared to the overweight category. A similar pattern was observed for the various levels of waist circumference, with percent change in fitness being less as at higher levels of baseline waist circumference in groups 3, 4, and 5 compared to group 1. For each year of age there was a significantly lower change in fitness. Moreover, individuals without a prior history of CVD had a 2.10% higher change in fitness compared to those with a prior history of CVD.

Data were reanalyzed using multiple imputation for missing fitness data and a similar pattern of results were observed (data not shown).

Change in LTPA

Change in LTPA was available for 2,221 participants (DSE = 1,103; ILI = 1,118). The change in LTPA was significantly greater in ILI (892±1694 kcal/wk) compared to DSE (108±1254 kcal/wk) (p<0.001). Characteristics for participants completing and not-completing the LTPA questionnaire were compared. At baseline, participants completing the LTPA questionnaire were significantly older (59.1±6.8 vs. 58.3±6.7 years), weighed more (103.1±19.1 vs. 98.4±19.0 kg), had a higher BMI (36.4±6.0 vs. 35.2±5.7 kg/m²), had a larger waist circumference (115.5±14.3 vs. 112.5±13.3 cm), fewer were non-smokers (49.0% vs. 51.2%), fewer had metabolic syndrome (5.0% vs. 6.8%), and had a lower HbA1c (7.2±1.1 vs. 7.3±1.2) than those not completing the LTPA questionnaire (p<0.05). Percent change in fitness was significantly less for participants completing the LTPA questionnaire (12.5±25.1% vs. 14.5±28.4%, p=0.01); however, there was no significant difference for percent change in body weight (4.6±7.4% vs. 4.5±7.5%).

Associations between Change in Fitness or Physical Activity and Weight Change

Correlation coefficients were computed to determine the association between change in both fitness and physical activity and change in measures of body weight. Results of these analyses are presented in Table 4. Overall, there was a significant association between an increase in fitness and reduction in both body weight (r=0.42) and BMI (r=0.42) (p<0.0001). These data indicate that as fitness increased there was a corresponding decrease in body weight and BMI. A similar pattern was found for both DSE and ILI. In addition, while somewhat lower in magnitude, there was a significant correlation between an increase in physical activity and weight loss (r=0.36) and reduction in BMI (r=0.36) (p<0.0001). Again, a similar pattern was observed when data were analyzed separately for DSE and ILI.

Fitness changes were analyzed with participants grouped based on percent weight change, baseline LTPA, and 1-year LTPA (Table 5). There was a significant increase for change in
fitness with greater levels of weight loss (p<0.0001). There was no effect of baseline LPTA on change in fitness; however, there was a dose-response observed between change in fitness and 1-year LTPA (p<0.0001). Similar patterns were observed for both ILI and DSE.

DISCUSSION

The ILI implemented in the Look AHEAD trial was effective in increasing physical activity, which contributed to both weight loss and improvement in cardiorespiratory fitness in overweight and obese individuals with type 2 diabetes. As shown in Figure 2, data adjusted for baseline fitness revealed that percent change in fitness was approximately 15 points higher in ILI compared to DSE. This magnitude of change in fitness is similar to the change reported for individuals with type 2 diabetes in response to short-term exercise training. For example, Eriksen et al. 17 reported a 9–15% improvement in fitness in response to a 5 week exercise training program, and Lee et al. 18 reported a 20% improvement in response to a 13-week exercise program. A meta-analysis conducted by Boule et al. 19 concluded that the mean improvement in fitness resulting from exercise in individuals with type 2 diabetes is approximately 11%. Within the multivariate analysis that also adjusted for weight change (see Table 3), ILI resulted in a 5% greater improvement in fitness compared to DSE, which is similar to the 5% improvement reported by Middlebrooke et al. 20. It is important to note that fitness was measured by Middlebrooke et al. 20 using a cycle ergometer, whereas fitness in the Look AHEAD study was measured using a motorized treadmill, yet similar changes in fitness were observed in these studies.

The ability of ILI to increase fitness is important as this may result in improved health outcomes in these participants with type 2 diabetes. Church et al. 9 reported that higher levels of fitness were associated with a delayed onset of cardiovascular disease events compared to lower levels of fitness in individuals with type 2 diabetes. Fitness in individuals with type 2 diabetes was approximately 14% higher in survivors of CVD mortality versus non-survivors across a mean follow-up period of 15.9±7.9 years, similar to the unadjusted 15 percentage point difference for improvement in fitness in ILI versus DSE in this study (see Figure 2). This is of importance for the Look AHEAD Study as the primary study question is to determine whether ILI results in lower CVD outcomes compared to DSE.

It should also be noted that there was an improvement in fitness in DSE. This may be due to some of the subjects randomized to the DSE intervention increasing their physical activity, which may have resulted in an improvement in fitness. As shown in Table 4, there was a significant but modest correlation between change in physical activity and change in fitness in the DSE group. Moreover, as shown in Table 5, subjects in DSE who reported higher physical activity at 1-year also had the greatest increases in fitness. Thus, these results suggest that some individuals may respond to a DSE intervention similar to the one implemented in this study, and this may result in improved physical activity and corresponding improved fitness. However, it is unclear from the analyses present here whether the observed improvement in fitness in DSE translated into improvements in diabetes control or CVD risk, and this warrants further investigation.
We observed an effect of ethnicity on change in fitness based on the bivariate analysis (see Table 2), with those identified as American Indian/Native American/Alaskan Native or African-American/Black having reduced changes in fitness compared to other represented ethnic groups. This may be a result of differences in the physiological response to exercise and weight loss, or possibly a result of differences in adoption of the lifestyle components of the ILI intervention. Further study to examine the factors contributing to this ethnicity effect is needed to understand this finding in the Look AHEAD study.

Studies demonstrating that higher levels of fitness can have a significant impact on health-related outcomes independent of body weight have resulted in the belief that interventions for overweight and obese adults should focus on improving fitness rather than weight loss per se. However, one must interpret these data with caution because of the limited inclusion of individuals with Class II (BMI: 35–39.9 kg/m$^2$) or Class III (BMI ≥40 kg/m$^2$) in these studies. For example, in the study of individuals with diabetes conducted by Church et al., the authors identified the lack of subjects classified as Class II or III obesity as a limitation of the study and cautioned about applying the findings to those individuals. The multivariate analysis of this current study showed that in fact the improvement in fitness is less in individuals with diabetes classified with Class II or III obesity compared to overweight individuals (see Table 3), with a trend towards significant between Class 1 obesity and overweight individuals (p=0.055). A similar pattern is observed across quintiles of waist circumference. This may be a result of the patterns in physical activity differing between individuals of varying levels of BMI, which may include differences in the intensity of the physical activity performed, and this warrants further investigation. Thus, it is important to understand the challenges to improving fitness in individuals with severe obesity while still recognizing the potential that fitness gains can have on health-related outcomes, independent of body weight.

The results should be interpreted within the context of potential strengths and weaknesses of this study. Strengths of this study include the ability to recruit and prospectively assess fitness in a large cohort of individuals with type 2 diabetes, the randomized nature of the study design, and the ability to objectively assess fitness in this cohort. Weaknesses may include the use of a submaximal rather than a maximal graded exercise test to assess the change in fitness and the subjective assessment of physical activity on a subsample of the subjects in this study.

In summary, an intensive lifestyle intervention involving both a reduction in energy intake and an increase in physical activity can result in significant weight loss and significant improvements in fitness at one year in overweight and obese adults with type 2 diabetes, and this increase is significantly greater than what is achieved with a diabetes support and education (DSE) intervention. In addition, the observed change in fitness resulting from ILI remained significant even after adjusting for other factors that may influence fitness (see Table 3 and Figure 2). These findings are significant because of the potential impact of physical activity on weight loss and change in fitness, with change in fitness potentially having an independent effect on health-related outcomes and chronic disease risk factors. Thus, individuals with diabetes should be encouraged by physicians and other health-care professionals to engage in sufficient amounts of physical activity. The Look AHEAD Study
is ongoing and will examine fitness following the fourth year of the intervention to further assess the long-term impact of ILI on weight loss, fitness, and related clinical outcomes in these adults with type 2 diabetes.

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The Johns Hopkins Medical Institutions Frederick L. Brancati, MD, MHS¹; Jeff Honas, MS²; Lawrence Cheskin, MD³; Jeanne M. Clark, MD, MPH³; Kerry Stewart, EdD³; Richard Rubin, PhD³; Jeanne Charleston, RN; Kathy Horak, RD

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Harvard Center

Massachusetts General Hospital: David M. Nathan, MD¹; Heather Turgeon, RN, BS, CDE²; Kristina Schumann, BA²; Enrico Cagliero, MD³; Linda Delahanty, MS, RD³; Kathryn Hayward, MD³; Ellen Anderson, MS, RD³; Laurie Bissett, MS, RD; Richard Ginsburg, PhD; Valerie Goldman, MS, RD; Virginia Harlan, MSW; Charles McKitrick, RN, BSN, CDE; Alan McNamara, BS; Theresa Michel, DPT, DSc CCS; Alexi Poulos, BA; Barbara Steiner, EdM; Joclyn Tosch, BA

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Beth Israel Deaconess Medical Center: George Blackburn, MD, PhD¹; Christos Mantzoros, MD, DSc³; Kristinia Day, RD; Ann McNamara, RN

¹Principal Investigator
²Program Coordinator
³Co-Investigator

All other Look AHEAD staffs are listed alphabetically by site.

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University of Colorado Health Sciences Center  James O. Hill, PhD1; Marsha Miller, MS, RD2; JoAnn Phillip, MS2; Robert Schwartz, MD3; Brent Van Dorsten, PhD3; Judith Regensteiner, PhD3; Salma Benekhoum MS; Ligia Coelho, BS; Paulette Cohrs, RN, BSN; Elizabeth Daenick, MS, RD; Amy Fields, MPH; Susan Green; April Hamilton, BS, CCRC; Jere Hamilton, BA; Eugene Leschinskyi; Michael McDermott, MD; Lindsey Munkwitz, BS; Loretta Rome, TRS; Kristin Wallace, MPH; Terra Worley, BA

Baylor College of Medicine  John P. Foreyt, PhD1; Rebecca S. Reeves, DrPH, RD2; Henry Pownall, PhD3; Ashok Balasubramanyam, MBBS3; Peter Jones, MD,3; Michele Burrington, RD; Chu-Huang Chen, MD, PhD; Allyson Clark, RD; Molly Gee, MEd, RD; Sharon Griggs; Michelle Hamilton; Veronica Holley; Jayne Joseph, RD; Patricia Pace, RD; Julieta Palencia, RN; Olga Satterwhite, RD; Jennifer Schmidt; Devin Volding, LMSW; Carolyn White

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St. Luke’s Roosevelt Hospital Center  Xavier Pi-Sunyer, MD1; Jennifer Patricio, MS2; Stanley Heshka, PhD3; Carmen Pal, MD3; Lynn Allen, MD; Diane Hirsch, RNC, MS, CDE; Mary Anne Holowaty, MS, CN

University of Pennsylvania  Thomas A. Wadden, PhD1; Barbara J. Maschak-Carey, MSN, CDE2; Stanley Schwartz, MD3; Gary D. Foster, PhD3; Robert I. Berkowitz, MD3; Henry Glick, PhD3; Shiriki K. Kumanyika, PhD, RD, MPH3; Johanna Broek; Helen Chomentowski; Vicki Clark; Canice Crerand, PhD; Renee Davenport; Andrea Diamond, MS, RD; Anthony Fabricatore, PhD; Louise Hesson, MSN; Stephanie Krauthamer-Ewing,
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University of Southern California Anne Peters, MD; Valerie Ruelas, MSW, LCSW; Siran Ghazarian, MD; Kathryn Graves, MPH, RD, CDE; Kati Konersman, MA, RD, CDE; Sara Serafin-Dokhan

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Central Resources Centers

DXA Reading Center, University of California at San Francisco Michael Nevitt, PhD; Susan Ewing, MS; Cynthia Hayashi; Jason Maeda, MPH; Lisa Palermo, MS, MA; Michaela Rahorst; Ann Schwartz, PhD; John Shepherd, PhD

Central Laboratory, Northwest Lipid Research Laboratories Santica M. Marcovina, PhD, ScD; Greg Strylewicz, MS

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Figure 1.
Flow Chart of Participant Randomization and Completion of Fitness Testing.
Figure 2.
Comparison of Percent Change in Fitness Adjusted for Baseline METs in DSE versus ILI.
*indicates significant difference between DSE and ILI and p<0.0001 Error bars are SE of the mean.
Table 1
Baseline demographic characteristics for participants with valid baseline and one-year fitness data.

| Variable                          | Overall     | DSE           | ILI           | P-value* |
|-----------------------------------|-------------|---------------|---------------|----------|
|                                   | Mean        | Overall       | Males         | Females  |
| Age at Baseline GXT              | 58.7±6.8 (N=4376) | 58.8±6.9 (N=2132) | 59.8±6.8 (N=873) | 58.6±6.8 (N=2244) | 59.9±6.7 (N=921) | 57.8±6.7 (N=1323) | 0.42 |
| BMI                               | 35.8±5.8 (n=4375) | 35.8±5.7 (N=2132) | 34.9±5.1 (N=873) | 36.5±5.9 (N=2243) | 35.1±5.7 (N=921) | 36.2±6.1 (N=1322) | 0.70 |
| Baseline Weight (kg)              | 100.4±19.0 (N=4376) | 100.5±18.5 (N=2132) | 108.4±17.6 (N=873) | 95.0±17.1 (N=1259) | 108.6±19.1 (N=921) | 104.5±17.5 (N=1323) | 0.74 |
| Diabetes Duration                 | 6.7±6.5 (N=4316) | 6.7±6.3 (N=2111) | 7.0±6.2 (N=867) | 6.5±6.4 (N=2205) | 7.1±6.5 (N=903) | 6.5±6.7 (N=1302) | 0.93 |
| HbA1c                             | 7.3±1.2 (N=4376) | 7.3±1.2 (N=2132) | 7.3±1.2 (N=873) | 7.2±1.2 (N=2244) | 7.2±1.2 (N=921) | 7.3±1.1 (N=1323) | 0.13 |
| Waist Circumference               | 113.7±13.9 (N=4376) | 113.7±13.5 (N=2129) | 117.9±12.7 (N=871) | 110.8±13.2 (N=1258) | 113.6±14.2 (N=2241) | 118.3±13.9 (N=918) | 110.4±13.6 (N=1323) | 0.81 |
| Baseline Maximum METs             | 7.3±2.0 (N=4376) | 7.3±2.0 (N=2132) | 8.1±2.1 (N=873) | 6.7±1.7 (N=2244) | 7.3±2.0 (N=921) | 6.5±1.7 (N=1323) | 0.88 |
| Baseline Submaximal METs**        | 5.2±1.5 (N=4376) | 5.1±1.6 (N=2132) | 5.7±1.6 (N=873) | 4.7±1.4 (N=2244) | 5.2±1.5 (N=921) | 4.8±1.3 (N=1323) | 0.24 |

DSE = Diabetes Support and Education Group
ILI = Intensive Lifestyle Intervention Group

* P-value represents the difference between DSE and ILI for overall subject comparisons.
** Using the criteria for determining the change in fitness from baseline to 1-year.
Table 2

Influence of gender, race, and baseline insulin use, diabetes severity, HbA1c, smoking history, metabolic syndrome, BMI, waist circumference, and treatment assignment on Percent Change in Fitness Adjusted for Baseline METs.

| Variable                           | Subgroup          | N     | LS Mean (SE) | P-Value | LS Mean (SE) | LS Mean (SE) |
|------------------------------------|-------------------|-------|--------------|---------|--------------|--------------|
|                                    | Overall           |       |              |         |              |              |
|                                    |                   |       |              |         |              |              |
| Age                                | 45 – 55 years     | 1362  | 17.25 (0.70) | <.0001  | 8.24 (0.96)  | 25.84 (0.93) |
|                                    | 56 – 65 years     | 2274  | 13.12 (0.54) |         | 6.18 (0.74)  | 19.56 (0.72) |
|                                    | 66 – 76 years     | 739   | 8.09 (0.96)  |         | −0.15 (1.28) | 16.40 (1.29) |
| Gender                             | Male              | 1794  | 17.28 (0.63) | <.0001  | 9.05 (0.84)  | 25.19 (0.83) |
|                                    | Female            | 2582  | 10.96 (0.52) |         | 3.19 (0.70)  | 18.09 (0.68) |
| Race                               | African American / Black (not Hispanic) | 676  | 9.69 (1.00) | <.0001  | 4.07 (1.36)  | 15.04 (1.33) |
|                                    | American Indian / Native American / Alaskan Native | 228 | 4.95 (1.71) |         | −0.23 (2.31) | 10.14 (2.31) |
|                                    | White             | 2806  | 15.22 (0.49) |         | 6.59 (0.66)  | 23.51 (0.65) |
|                                    | Hispanic          | 527   | 13.39 (1.12) |         | 5.57 (1.57)  | 20.30 (1.47) |
|                                    | Asian/Pacific Islander / Other/Mixed / Missing | 139 | 13.44 (2.19) |         | 6.81 (3.06)  | 19.33 (2.87) |
| Baseline Insulin Use               | No                | 3592  | 13.99 (0.45) | 0.0179  | 6.02 (0.59)  | 21.57 (0.58) |
|                                    | Yes               | 784   | 11.56 (0.93) |         | 4.36 (1.27)  | 18.34 (1.23) |
| Baseline Diabetes Medication       | No Diabetic Meds, No Insulin | 565   | 16.02 (1.09) | 0.0163  | 9.78 (1.52)  | 21.65 (1.44) |
|                                    | Diabetic Meds Only| 2969  | 13.68 (0.48) |         | 5.33 (0.65)  | 21.64 (0.64) |
|                                    | Insulin Only      | 173   | 10.20 (1.97) |         | 3.96 (2.68)  | 16.33 (2.66) |
|                                    | Insulin and Diabetic Meds | 611  | 11.96 (1.05) |         | 4.49 (1.45)  | 18.91 (1.40) |
| Baseline HbA1c                     | < 6.0             | 332   | 16.33 (1.42) | 0.0085  | 8.51 (1.93)  | 24.10 (1.92) |
|                                    | 6.0 – 6.5         | 780   | 14.65 (0.93) |         | 5.48 (1.34)  | 21.90 (1.19) |
|                                    | 6.5 – 7.0         | 929   | 14.91 (0.85) |         | 6.54 (1.15)  | 23.38 (1.15) |
|                                    | 7.0 – 8.0         | 1331  | 12.28 (0.71) |         | 4.31 (0.96)  | 20.21 (0.96) |
|                                    | 8.0 – 9.0         | 642   | 13.07 (1.02) |         | 6.45 (1.43)  | 18.82 (1.34) |
|                                    | > 9.0             | 362   | 10.69 (1.36) |         | 5.55 (1.78)  | 16.55 (1.90) |
| Baseline Smoking                   | Never             | 2219  | 12.56 (0.55) | 0.0348  | 4.70 (0.75)  | 20.29 (0.74) |
|                                    | Past              | 1970  | 14.64 (0.59) |         | 6.82 (0.81)  | 21.84 (0.77) |
|                                    | Present           | 177   | 14.07 (1.95) |         | 6.88 (2.74)  | 20.29 (2.55) |
| Variable                        | Subgroup       | N    | Overall LS Mean (SE) | P-Value | DSE LS Mean (SE) | ILI LS Mean (SE) |
|--------------------------------|----------------|------|----------------------|---------|------------------|-----------------|
| Baseline Metabolic Syndrome   | No             | 275  | 14.55 (1.57)         | 0.5112  | 7.07 (2.23)      | 20.89 (2.03)    |
|                                | Yes            | 4101 | 13.49 (0.41)         | 5.64 (0.55) | 21.00 (0.54)   |
| Baseline BMI                   | Overweight (25 – 29.9) | 674  | 15.51 (1.01)         | 0.0628  | 9.27 (1.42)      | 20.91 (1.31)    |
|                                | Class I (30 – 34.9) | 1541 | 14.08 (0.67)         | 6.32 (0.91) | 21.43 (0.88)   |
|                                | Class II (35 – 39.9) | 1212 | 12.85 (0.75)         | 5.21 (1.00) | 20.82 (1.02)   |
|                                | Class III (40 or greater) | 944  | 12.19 (0.87)         | 3.05 (1.18) | 20.57 (1.14)   |
| Baseline WC                    | 1              | 837  | 15.33 (0.90)         | 0.0002  | 7.94 (1.28)      | 21.52 (1.16)    |
|                                | 2              | 876  | 16.13 (0.88)         | 8.85 (1.15) | 24.24 (1.21)   |
|                                | 3              | 1034 | 11.45 (0.80)         | 4.00 (1.12) | 18.11 (1.06)   |
|                                | 4              | 710  | 13.41 (0.97)         | 4.55 (1.29) | 22.83 (1.33)   |
|                                | 5              | 913  | 11.90 (0.87)         | 3.49 (1.19) | 19.48 (1.14)   |
| Baseline CVD history           | No             | 3786 | 14.04 (0.42)         | 0.0015  | 6.03 (0.58)      | 21.73 (0.56)    |
|                                | Yes            | 590  | 10.40 (1.07)         | 3.69 (1.49) | 16.39 (1.40)   |
| Treatment Assignment           | DSE            | 2132 | 5.73 (0.52)          | <0.001  |                  |                 |
|                                | ILI            | 2244 | 20.99 (0.54)         |         |                  |                 |

**WC = Waist Circumference**

Males: WC: 1 = < 105 cm; 2 = 105–114.9 cm; 3 = 115–119.9 cm; 4 = 120–129.9 cm; 5 = > 130 cm

Females: WC: 1 = < 100 cm; 2 = 100–104.9 cm; 3 = 105–114.9 cm; 4 = 115–119.9 cm; 5 = > 120 cm
### Table 3

Final multivariate model* examining percent fitness change.

| Variable                                          | Estimate | Standard Error | t value | P-value |
|----------------------------------------------------|----------|----------------|---------|---------|
| ILI vs DSE                                         | 5.06     | 0.80           | 6.31    | <.0001  |
| Female vs Male                                     | 2.64     | 2.57           | 1.02    | 0.3057  |
| Baseline MaxMETS                                   | -5.90    | 0.34           | -17.20  | <.0001  |
| Baseline MaxMETS × Gender (Female versus Male)     | -1.82    | 0.47           | -3.88   | 0.0001  |
| 1 Year weight change                              | -0.57    | 0.02           | -24.22  | <.0001  |
| Baseline BMI categories                            |          |                |         | 0.0002  |
| Class I (30 – 34.9) vs Overweight (25 – 29.9)     | -2.27    | 1.18           | -1.92   | 0.0552  |
| Class II (35 – 39.9) vs Overweight (25 – 29.9)    | -3.62    | 1.47           | -2.47   | 0.0137  |
| Class III (40 or greater) vs Overweight (25 – 29.9)| -7.32    | 1.73           | -4.23   | <.0001  |
| Baseline Waist circumference categories            |          |                |         | 0.0019  |
| WC2 versus WC1 **                                 | 0.04     | 1.21           | -0.03   | 0.9750  |
| WC3 versus WC1 **                                 | -3.36    | 1.29           | -2.61   | 0.0091  |
| WC4 versus WC1 **                                 | -3.49    | 1.54           | -2.27   | 0.0232  |
| WC5 versus WC1 **                                 | -5.46    | 1.65           | -3.32   | 0.0009  |
| Baseline Age                                      | -0.77    | 0.06           | -13.85  | <.0001  |
| Without Baseline history of CVD                   | 2.10     | 1.04           | 2.03    | 0.0426  |

* Model adjusted for clinic.

** Classification of Waist Circumference Quintiles:

- Males: WC1 = <105 cm; WC2 = 105–114.9 cm; WC3 = 115–119.9 cm; WC4 = 120–129.9 cm; WC5 = >130 cm
- Females: WC1 = <100 cm; WC2 = 100–104.9 cm; WC3 = 105–114.9 cm; WC4 = 115–119.9 cm; WC5 = >120 cm

Variables Removed from the Final Model:

- Treatment × Clinic, Gender × Treatment, Gender × Clinic, Gender × Weight change, Gender × Race, Race, Gender × BMI (categorical), Gender × Waist circumference (categorical), Gender × Age, Gender × Diabetes Medication, Diabetes Medication, Gender × HbA1c (categorical), HbA1c (categorical), Gender × Beta Blocker use, Beta Blocker use, Gender × Smoking, Smoking, Gender × Metabolic Syndrome, Metabolic Syndrome, Gender × Baseline CVD, Gender × Diabetes duration, Diabetes duration, Gender × Hypertension, Hypertension.
Table 4
Correlations between change in body weight and BMI with change in fitness and leisure-time physical activity (LTPA).

| Variables                        | Overall     | DSE Group   | ILI Group   |
|----------------------------------|-------------|-------------|-------------|
| Weight Change and Percent Change in Fitness | − 41 P<.0001 N=4375 | −.21 P<.0001 N=2131 | −.39 P<.0001 N=2244 |
| Weight Change and Change in LTPA | −.36 P<.0001 N=2220 | −.14 P<.0001 N=1103 | −.26 P<.0001 N=1117 |
| BMI Change and Percent Change in Fitness | −.41 P<.0001 N=4374 | −.20 P<.0001 N=2131 | −.39 P<.0001 N=2243 |
| BMI Change and Change in LTPA | −.36 P<.0001 N=2219 | −.14 P<.0001 N=1103 | −.26 P<.0001 N=1116 |
| Percent Change in Fitness and Change in LTPA | .25 P<.0001 N=1990 | .11 P<.001 N=963 | .20 P<.0001 N=1027 |

Note: A negative correlation coefficient reflects that a larger increase in fitness or physical activity is associated with a larger decrease in body weight or BMI.
| Weight change category       | Overall    | DSE        | ILI        |
|-----------------------------|------------|------------|------------|
|                             | N          | Mean (SE)  | P-value    | N          | Mean (SE)  | P-value    | N          | Mean (SE)  | P-value    |
| Weight gain                 | 1257       | 2.676 (0.752) | <.0001    | 1076       | 2.248 (0.7)   | <.0001    | 181        | 5.44 (2.274) | <.0001    |
| Weight loss of 0–4.99%      | 1629       | 7.85 (0.651)   |           | 1018       | 6.587 (0.711) |           | 611        | 10.007 (1.186) |           |
| Weight loss of 5–9.99%      | 1001       | 16.396 (0.829) |           | 251        | 11.572 (1.46) |           | 750        | 17.886 (1.038) |           |
| Weight loss of ≥10%         | 1012       | 32.074 (0.806) |           | 79         | 27.275 (2.563) |           | 933        | 32.461 (0.928) |           |
| Baseline LTPA Category      |            |            |            |            |            |            |            |            |            |
| < 500 kcal/wk               | 1197       | 12.611 (0.798) | 0.936     | 602        | 4.158 (0.913) | 0.9236    | 595        | 20.712 (1.203) | 0.5998    |
| 500–999 kcal/wk             | 495        | 12.866 (1.215) |           | 250        | 4.738 (1.388) |           | 245        | 20.698 (1.833) |           |
| 1000–1499 kcal/wk           | 264        | 12.382 (1.647) |           | 136        | 5.517 (1.893) |           | 128        | 18.57 (2.471)   |           |
| ≥1500 kcal/wk               | 444        | 11.812 (1.282) |           | 213        | 4.73 (1.498)  |           | 231        | 18.067 (1.894) |           |
| 1-year LTPA Category        |            |            |            |            |            |            |            |            |            |
| < 500 kcal/wk               | 788        | 5.96 (0.954)   | <.0001    | 559        | 2.285 (0.93)  | 0.0005    | 229        | 14.647 (1.907) | <.0001    |
| 500–999 kcal/wk             | 401        | 10.084 (1.285) |           | 200        | 4.172 (1.483) |           | 201        | 15.929 (1.984) |           |
| 1000–1499 kcal/wk           | 294        | 14.533 (1.515) |           | 126        | 5.916 (1.978) |           | 168        | 20.687 (2.162) |           |
| ≥1500 kcal/wk               | 777        | 19.293 (0.912) |           | 241        | 9.09 (1.353)  |           | 536        | 23.74 (1.192)  |           |

LTPA = Leisure Time Physical Activity

Table 5
Percent fitness change from baseline to one-year by weight change and LTPA categories.