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Can Lifestyle Interventions Do More than Reduce Diabetes Risk? Treating Depression in Adults with Type 2 Diabetes with Exercise and Cognitive Behavioral Therapy

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Abstract

The epidemic of metabolic syndrome, prediabetes, and type 2 diabetes is global in scope and comprehensive in its impact on individuals, health care systems, and societies. One in four patients with diabetes will experience depression in their lifetime. Comorbid depression is associated with poorer outcomes, greater functional disability, and early mortality. Prior studies have demonstrated beneficial effects of exercise as an efficacious form of treatment for depression in the general population. Few studies have evaluated this strategy in patients with prediabetes or type 2 diabetes. Program ACTIVE (Appalachians Coming Together to Increase Vital Exercise) was designed to treat depression among adults with type 2 diabetes by pairing aerobic activity with individual cognitive behavioral therapy. This combination treatment approach has been shown to be feasible to implement in a rural environment and promising in terms of depression, diabetes, and cardiovascular outcomes. Data from this study suggest that exercise can be used to achieve multiple benefits for adults with type 2 diabetes. Future work to compare this approach to singular treatment strategies for adults at risk for type 2 diabetes is needed.

Keywords

Depression; Type 2 diabetes; Exercise; Cognitive behavioral therapy; Lifestyle interventions

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Introduction

Type 2 diabetes mellitus (T2DM) represents a growing burden to the health, welfare, and productivity of individuals in underserved urban and rural communities [1, 2]. Poverty, socioeconomic stress, and sedentary lifestyle have been shown to increase the risk for the development of obesity and T2DM [2, 3] as well as morbidity and premature mortality of T2DM [4–6].

Patients with T2DM are two times more likely to experience depression in their lifetime than their peers without diabetes, having an overall prevalence ranging from 25% to 27% [7]. This rate exceeds those found in the general population and is particularly troublesome when diabetes outcomes and associated costs are considered.

Depressive symptoms have been shown to be associated with worsened blood glucose levels [8] and diabetes complications [9] such as coronary heart disease [10]. There is increasing evidence of significant functional [11], financial [12], and behavioral costs (eg, poorer adherence to diet, exercise, and medications; [13, 14]) for patients with diabetes and depression compared to those with diabetes alone. Depression has also been associated with decrements in generic and diabetes-specific quality of life [15, 16]. Finally, increased risk of early mortality has been found to be associated with both conditions at higher rates than either condition alone [17, 18], with mortality attributable to various causes in addition to cardiovascular disease [19].

Exercise has been shown to have a reciprocal relationship to depression in a variety of studies making use of samples with prediabetes and T2DM. Not surprisingly, depression has been found to be associated with lower levels of physical activity [20, 21] among patients with T2DM. In a meta-analysis comprised of 12 studies examining the relationship between exercise and physical activity in T2DM adult samples, Lysy et al. [21] found that depressed patients were 1.22 to 1.9 times more likely to be physically inactive. Likewise, physically inactive adults with T2DM were 1.72 to 1.75 times more likely to be depression compared to those who were more active. The authors note that the majority of these studies (N = 10) reported cross-sectional findings, thereby limiting the ability to attribute causality to these relationships.

Katon et al. [22••] followed a cohort of adults with T2DM treated for depression in the IMPACT study over a 5-year period, examining physical activity and dietary data at baseline and 5-year follow-up. Participants were categorized by depression status at year 5 (improved, worsened, persistent, and no depression). Analyses of lifestyle and depression trajectories over time indicated that those with no depression and improved depression showed greater improvement or maintenance (respectively) of physical activity than those whose depression worsened or persisted over the follow-up period. For those with improved depression, physical activity declined over time compared to those who were never depressed. These findings suggest that physical activity levels continue to decline once depression develops, even if improvements in mood symptoms are achieved.

Exercise has been demonstrated to be an effective approach for diabetes prevention [23], diabetes self-management, and the treatment of depression in nondiabetes samples [24–26]. However, evidence is limited on the use of physical activity as an effective treatment for depression among adults with T2DM. In a meta-analysis of 37 exercise treatment studies, Craft and Landers [26] found an overall significant effect size (Cohen's d = 0.72) in the reduction of clinical depression in general populations using predominantly laboratory-based exercise protocols. Blumenthal et al. [24] evaluated aerobic exercise as a treatment for depression among older adults without diabetes in two separate studies. In the first study, participants were randomized to sertraline, aerobic activity, or combination treatment

(exercise + selective serotonin reuptake inhibitor [SSRI]). Exercise and combination therapy were as efficacious as sertraline in ameliorating depression; however, participants in the exercise intervention also showed the lowest rates of depression relapse (8%) compared to the other two treatment conditions (38% medication, 31% combination) [25]. In a second study, Blumenthal et al. [27] compared home-based exercise, laboratory exercise, SSRI, and placebo among older adults with major depressive disorder. In this trial, comparable rates of depression remission (ie, 35% to 45%) were found across the four treatment groups.

Few studies have examined exercise as a treatment for depression among adults at risk or diagnosed with T2DM. Levinger et al. [28] conducted a 2x2 randomized controlled trial to assess the impact of 10 weeks of resistance training on depressive symptoms in a sample of 55 adults with either high (defined as 2 or more metabolic risk factors) or low (defined as 1 or none metabolic risk factors) risk for T2DM. Among high-risk individuals, resistance training significantly improved depressive symptoms compared to controls. Change in muscle strength was inversely correlated with depressive symptoms ($r = -0.46$; $P < 0.008$). No significant changes in mood symptoms were observed between treatment and controls in the low-risk group.

Piette et al. [29••] conducted a telephone-based counseling and walking intervention in a sample of 291 adults with T2DM and elevated depressive symptoms. Participants were randomized to walking and 12 weeks of telephone-based counseling (plus 9 booster sessions) or usual care. Participants receiving the intervention demonstrated improvements in depressive symptoms (58% reduced symptoms vs 39% in the control group), increased number of steps as measured using a pedometer, and improvements in systolic blood pressure (4.26-mm Hg decrease). No changes in hemoglobin A_{1c} (HbA_{1c}) were observed by group at the 12-month follow-up. In this study, depression was assessed using solely self-report questionnaires, thereby capturing a potentially lower level of depressive symptomatology.

As this evidence from general population samples and the few existing studies in diabetes suggest, exercise as a treatment for depression in patients with T2DM not only has the potential to improve depressive symptoms through behavioral activation, it may also positively contribute to diabetes management and improved psychosocial outcomes such as diabetes-related quality of life, self-efficacy, and social support. However, greater specificity in the diagnosis of depression (compared to depressive symptoms) and measurement of physical activity outcomes are needed to demonstrate the effectiveness of this approach for adults with T2DM.

A combination behavioral approach to the treatment of depression among adults with T2DM, entitled Program ACTIVE (Appalachians Coming Together to Increase Vital Exercise), was developed for the rural Appalachian region. A pilot and feasibility study was conducted to assess the impact of exercise (modeled after the Diabetes Prevention Program [DPP] Lifestyle Intervention) and cognitive behavioral therapy (CBT) on changes in depression, glycemic control, self-care behaviors, social support, and quality of life in a sample of adults with T2DM and depression. The study aims were to evaluate: 1) the feasibility of implementing a combination approach using community-based aerobic exercise and CBT as a treatment modality for depression among patients with T2DM; 2) changes in depression and glycemic control outcomes at post-intervention (POST) and 3-month follow-up assessment (3 months); 3) adherence to exercise and changes in aerobic fitness and blood lipids as an index of cardiovascular risk, at POST and 3 months; 4) changes in diabetes-specific and generic quality of life and social support from baseline to follow-up; and 5) participant satisfaction with a combination approach to depression treatment.

Methods

The study was a single-arm repeated-measures intervention design, approved by the Ohio University Institutional Review Board. Participants for Program ACTIVE were recruited from physician practices, local media, and community advertisements throughout southeastern Ohio and western West Virginia.

To ensure maximum levels of participant safety and appropriateness for the intervention, the following inclusion criteria were used: age 18 years or older, ambulatory status, diagnosis of T2DM for 1 year duration or longer, and current major depression disorder without psychotic features (MDD) as the primary psychiatric diagnosis. Medical exclusion criteria included: stage 2 hypertension (as defined by Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure), recent cardiac events and/or laser surgery for proliferative retinopathy, history of stroke, lower limb amputation, a sensory peripheral neuropathy, aortic stenosis or other severe valvular heart disease, atrial fibrillation, severe chronic obstructive pulmonary disease (eg, basal oxygen), New York Heart Association class III or IV heart failure, and orthopedic conditions that would preclude physical activity or medical instability. Psychiatric exclusion criteria included: active suicidal ideation or a history of suicide attempt, lifetime history of bipolar depression or any psychotic disorder, and current substance abuse or dependence disorder. Participants currently prescribed antidepressant medications were enrolled if medication dosages remained constant for 6 weeks prior to screening, thereby allowing sufficient time to assess medication failure. Participants who reported a prescribed change in medication dose or type for 6 weeks or less were excluded or deferred for later screening. Once enrolled, participants were asked to refrain from making changes to their depression and diabetes medications until the conclusion of the study.

After obtaining consent, each participant completed a 1- to 2-week baseline assessment period followed by the active intervention period (12 weeks). Participants' primary care physicians were contacted to complete a checklist of exclusionary medical diagnoses. Participants who met all study criteria were scheduled for their first exercise and CBT sessions within 1 to 3 weeks of the baseline assessment completion.

The POST assessment was scheduled 1 to 2 weeks following the intervention. A final follow-up assessment contact was conducted 3 months after the POST assessment.

Measures

Measures collected throughout the study protocol are described below. Demographic characteristics were collected at baseline via a self-administered questionnaire including age, ethnicity, marital status, income, educational status, work status, and health insurance status.

Structured Clinical Interview for the DSM-IV-TR (SCID)—The SCID [30] was used to assess lifetime and current diagnoses of Axis I disorders using the American Psychiatric Association Diagnostic and Statistical Manual, Fourth Edition, Text Revision (DSM-IV-TR) classification. Lifetime psychiatric history was assessed at baseline with follow-up periods assessed at POST and 3 months. The SCID is a semi-structured diagnostic face-to-face interview that assesses overall psychosocial functioning and the presence/absence of clinically significant psychiatric symptoms, syndromes, and disorders. Interviewers were trained to reliability on practice interviews to establish consistency in clinical thresholds for symptom presence/absence. The SCID has been shown to have adequate inter-rater reliabilities ($\kappa = 0.61$-0.68), test-re-test reliabilities ($r = 0.64$-0.69 for major depression), and validity. The Principal Investigator (PI; MdG) provided training to novice and Masters-level interviewers who completed 15 hours of didactic training and 25 hours of taped practice

interviews. Practice interview tapes were reviewed and scored by the PI. κ statistics were calculated for each interviewer who completed training and ranged from κ = 0.90 to 1.00. SCID interviews were reviewed by the PI for reliability and quality assurance. A case conference process was used to determine all Axis I diagnoses at each time point evaluation. Discrepancies in diagnostic opinions were discussed by the interview team until consensus was reached.

Beck Depression Inventory (BDI)—The BDI is a 21-item self-report questionnaire used to assess symptoms of depression [31] that correspond to DSM-IV-TR diagnostic criteria. The measure was administered at each assessment and CBT session. The BDI-II has been shown to have excellent test-retest reliability (r = 0.93) and inter-item correlations (ranging from r = 0.91-0.95) when used in general populations [31] and diabetes samples [32].

Diabetes Quality of Life Measure (DQOL)—The DQOL is a 46-item self-administered questionnaire used to assess diabetes-specific quality of life. Test-retest reliability in adults has been found to be r = 0.92. Inter-item correlations for T2DM patients has been found to be α = 0.70. The measure has shown excellent validity in T2DM patient samples [33, 34].

SF-36 Quality of Life Measure (SF-36)—The SF-36 is a 36-item self-administered questionnaire used to assess general quality of life [35]. Internal consistency in adult samples has been found to be r = 0.81 to 0.88.

Chronic Illness Resource Survey (CIRS)—The CIRS is a 33-item modified self-administered questionnaire that measures perceived social support in the following domains: doctor and health care team, family, personal, neighborhood, community, media and policy, community organizations, and work (if applicable). At each assessment, participants rated the degree of support during the previous 3 months in each domain on a 5-point Likert scale, from 1 = “Not at all” to 5 = “A great deal.” The short form has shown acceptable internal consistency (α = 0.79), test-retest reliability (0.89), and construct validity and prospective criterion validity (0.61) in diabetes and other chronic illness samples [36].

Participant satisfaction questionnaire—The participant satisfaction questionnaire is a 25-item survey that was administered at POST to assess satisfaction with each component of the intervention including overall satisfaction, exercise classes, CBT sessions, weekly intervention contacts, contact with study personnel, and printed materials. Participants rated satisfaction on a 5-point Likert scale, where 1 = “Very dissatisfied” and 5 = “Very satisfied.”

Physical activity diaries—Physical activity diaries adapted from the DPP Lifestyle Balance Intervention condition [37] were used to record physical activity for a 1-week period at each assessment and weekly throughout the 12-week intervention period. Total minutes of physical activity (exercise) per week, pre- and post-exercise self-monitored blood glucose, nature of activity, and whether activity was performed individually, or as a group activity, were recorded by participants.

Number of steps—Number of steps were measured daily using the Yamax Digiwalker SW200 pedometer (Optimal Health Products, Bensenville, IL) and reported as 1-week totals prior to each assessment time point and throughout the intervention period.

Glycated hemoglobin (HbA_{1c})—Glycated hemoglobin (HbA_{1c}) was measured using the DCA2000+ Analyzer (Bayer Diagnostics, Wayne, NJ) at each assessment time point. The DCA2000+ Analyzer provides glycated hemoglobin data from whole-blood samples using the measurement of glycated fractions of HbA_{1c}, which reflects the glucose level in the

blood over a 2- to 3-month time span. The reference range for HbA_{1c} samples was 4.3% to 5.7%.

Fasting blood lipid profile—Fasting blood lipid profile including high-density lipoprotein cholesterol (HDL-C), total cholesterol, low-density lipoprotein cholesterol (LDL-C) (direct), and triglycerides was collected at each assessment time point. Samples were collected and analyzed by O'Bleness Hospital Laboratory, Athens, Ohio.

Resting, exercise, and recovery cardiovascular assessments—Resting, exercise, and recovery cardiovascular assessments were made to ensure the safety of potential participants in the exercise intervention at baseline and to measure changes in cardiovascular fitness at POST assessment. Resting blood pressure was measured via auscultation with a calibrated sphygmomanometer. A maximal graded exercise test (GXT) was utilized to assess aerobic capacity and exercise tolerance at baseline and POST assessments. Each individual completed the GXT on a Monark 874E cycle ergometer (Uppsala, Sweden) under the supervision of the study medical director and exercise technician to volitional fatigue or to a symptom/response limited end point [38, 39]. Cardiovascular responses (12-lead electrocardiogram, blood pressure, and heart rate) were evaluated at each stage, throughout the GXT and recovery. Pulmonary gas exchange was measured throughout the GXT to determine peak aerobic fitness (VO_2 peak) utilizing a Parvo Medics' TrueOne metabolic measurement system (Parvo Medics, Sandy, UT) and exercise tolerance was quantified as total time for the GXT and cardiovascular response for given submaximal workloads.

Physical examination and medical history—Past medical history data were gathered via interview at baseline, POST, and 3-month assessments by the study medical director for diabetes-specific physiologic characteristics such as diabetes type, diabetes duration, height, weight, prescribed diabetes treatment regimen, medical contraindications for participation, accuracy of diagnoses, and number and severity of diabetes complications.

Anthropometric measurements—Anthropometric measurements were taken to reflect changes in body composition, body mass index (BMI), and regional fat distribution. Height and weight were measured on a calibrated Detecto Physician's Scale with stadiometer to the nearest half inch and weight to the pound. Waist circumference (girth) was assessed with a constant tension tape measure (Gulick tape) at the narrowest portion of the torso, while a hip measurement was made at the maximum posterior extension of the buttocks according to standard procedures [39]. Waist-to-hip ratio was calculated [39].

Intervention Design

The interdisciplinary intervention was comprised of manualized CBT and community-based aerobic activity based on the Lifestyle Intervention arm of the DPP [37].

CBT sessions were conducted by advanced graduate students in the doctoral program in clinical psychology at Ohio University who received training in the manualized approach under the supervision of the author (MdG). Participants received 10 sessions of individual therapy in which they designated treatment goals tailored to their needs.

The exercise intervention consisted of 12 weeks of community-based exercise in which participants were encouraged to engage in 150 minutes of aerobic activity per week. To facilitate safe exercise practice, six exercise classes with supervision by trained exercise physiologists were provided to participants in conjunction with free passes to partnering community exercise facilities over the 12-week intervention period. In addition, participants had weekly contact with study personnel to encourage adherence to the exercise protocol

and monitor safety [40]. A complete description of the intervention is provided elsewhere [41].

Statistical Analyses

Statistical analyses were conducted using SAS 9.1e. Intent-to-treat analyses were used for all outcomes data in which the last known value for an individual was carried forward to subsequent time points in the event of missing data. Outcomes at POST and 3 months were compared to baseline values using paired *t* tests, with *P* values less than 0.05 indicating statistical significance. Multiple regression analyses were conducted to assess intervention-related predictors (eg, exercise minutes achieved over the intervention) of diabetes and depression outcomes at POST, using HbA_{1c} and BDI scores as continuous variables.

Results

A total sample of $N = 50$ participants were enrolled in the intervention, with $N = 40$ (80%) participants completing the intervention, POST, and 3-month assessments. Reasons for non-completion included diagnosis of another medical disorder (eg, prostate cancer, gout), non-study–related injuries (eg, foot, knee surgeries), or desire to pursue additional psychiatric treatment.

Sample Characteristics

Demographic characteristics for the intervention sample are shown in Table 1. Participants were predominantly female (68%), married (74%), and evenly distributed across educational levels. The modal annual household income was $21,000 to 40,000 (28.6%). Participants had a mean age of 57 (SD 9.0) years. The mean duration of T2DM was 10.5 (SD 6.6) years. The mean BMI was 35.0 kg/m^2 (SD 7.1).

Depression Outcomes

Values for outcome variables at each study time point and comparisons between baseline and follow-up values are shown in Table 2. Sixty-six percent of participants at POST and 3 months no longer met criteria for MDD. Assessment of depressive symptoms (BDI) improved at POST (-10.4, SD 9.8; $P < 0.01$) and 3 months (-9.8, SD 11.0; $P < 0.01$) compared to baseline. Mean BDI scores at baseline fell into the moderate depression range, whereas average scores at POST and 3 months were found to be in the mild range.

Glycemic Control Outcomes

At baseline assessment, the mean HbA_{1c} was 7.6% (SD 1.8). HbA_{1c} decreased by 0.41% at POST (SD 1.4%, $p<.05$). Although HbA_{1c} was slightly decreased at 3 months (-0.32%; SD 1.3%, not significant), it did not reach statistical significance.

Mean fasting glucose for the sample was 161.0 mg/dL (SD 56.0) at baseline. Significant decreases in fasting glucose were observed at POST (M = -4.7 mg/dL; SD 51.4; $P < 0.05$) and 3 months (M = -23.1 mg/dL; SD 44.0; $P < 0.01$) compared to baseline values.

Exercise and Cardiovascular Risk Outcomes

Participants completed the intervention protocol within 14.5 weeks (SD 3.5 weeks). As shown in Table 2, participants engaged in an average of 129 minutes per week of activity at baseline. Throughout the intervention period, participants completed an average of 187 minutes per week of aerobic activity (range: 31-479) in excess of the treatment goal of 150 minutes per week of aerobic activity. Participants completed an average of 30,223 steps per week (range: 5427-77,979) during the intervention period. These improvements were also

reflected in changes in self-ratings on the Godin Physical Activity Measure at POST and 3 months and ratings of exercise-related self-efficacy at POST assessment.

Evaluation of exercise capacity showed improvement in relative VO_2 peak exercise levels compared to baseline (M = 1.11 mL/kg/min; SD 2.1; $P < 0.01$) as did absolute VO_2 peak exercise values (M = 0.09 L/min; SD 0.18; $P < 0.01$), indicating improvements in aerobic fitness with changes in workload, independent of changes in body weight. Mean BMI and waist-to-hip ratios did not change from baseline at POST or 3 months.

Significant improvements were observed in LDL-C at POST (M = -11.0; SD 28.9; $P < 0.01$) compared to baseline values. HDL-C, triglycerides, and total cholesterol did not show significant changes over time.

Psychosocial Outcomes

Diabetes-specific and general quality of life improved at POST and 3 months compared to baseline. Within the general quality-of-life measure, significant improvements were found for physical functioning (M = 8.0; SD 15.7; $P < 0.01$; M = 7.0; SD 13.1; $P < 0.01$), performance of one's physical role (M = 10.2; SD 27.0; $P < 0.05$; M = 11.2; SD 29.3; $P < 0.05$) scores, and pain-related quality of life at POST (M = 4.3; SD 14.3; $P < 0.05$). Evaluation of diabetes-specific quality of life indicated that participants experienced improvements in overall health, the impact of diabetes on quality of life, and satisfaction with diabetes at POST and 3 months compared to baseline.

Participants were also asked to report their perceived levels of support for managing their chronic illness using a social ecological approach in which participants rated support from themselves, family and friends, neighborhood, community, and their health care team. Participants reported increased self-support for chronic illness management at the end of the intervention and increased support from their neighborhood environment and community at POST and 3 months, indicating a favorable response to the presence of the intervention program in their community.

Finally, participants reported high levels of satisfaction (ie, very satisfied) with the intervention as a whole (82%), CBT sessions (94%), exercise classes (74%), and use of the pedometer (80%).

Predictors of Depression and Diabetes Outcomes

Pearson correlation analyses indicated a significant correlation ($r = 0.43$, $P < 0.05$) between changes in depression severity (BDI) and changes in HbA_{1c} from baseline to POST assessment. Multiple regression analyses were conducted to assess the baseline and intervention-related predictors of depression and glycemic control outcomes. Total number of CBT sessions attended by participants (as a measure of “dose” of CBT) significantly predicted depression severity at POST, after controlling for depression severity at baseline, age, home ownership, total household income, and marital status ($F(6,41) = 10.2$; $P < 0.0001$; $R^2 = 0.60$). Participants who attended more CBT sessions over the intervention (higher “dose”) reported decreased depression symptoms following the intervention ($\beta = -0.39$; $P < 0.01$; $\Delta R^2 = 0.14$).

Number of minutes of exercise reported over the intervention period (as a measure of exercise “dose”) was added to the model above. Although the overall model was significant, the number of minutes or cumulative steps did not significantly predict depressive symptoms at POST.

Multiple regression analyses also were conducted to assess intervention-related predictors of HbA_{1c} at POST. Results indicated that the total number of exercise minutes achieved over the intervention (exercise "dose") significantly predicted HbA_{1c} at POST, after controlling for HbA_{1c} at baseline, age, home ownership, total household income, and marital status ($F(6,42) = 9.54$; $P < 0.0001$; $R^2 = 0.58$). Participants who achieved a higher total number of exercise minutes over the intervention reported lower HbA_{1c} at POST ($\beta = -0.29$; $P < 0.01$; $\Delta R^2 = 0.07$). Similarly, total number of exercise steps achieved over the intervention significantly predicted HbA_{1c} at POST, after controlling for HbA_{1c} at baseline, age, home ownership, total household income, and marital status ($F(6,42) = 10.73$; $P < 0.0001$; $R^2 = 0.61$). Participants who achieved more exercise steps over the intervention reported lower HbA_{1c} at POST ($\beta = -0.35$; $P < 0.01$; $\Delta R^2 = 0.10$). When number of CBT sessions attended was added to the model, it was not a significant predictor of HbA_{1c} at POST, indicating that exercise alone significantly predicted changes in HbA_{1c} following the intervention.

Discussion

Lifestyle interventions have been shown to be effective in preventing the onset of T2DM as well as serving as a cornerstone to effective diabetes self-management. While depression has been understood to be a significant comorbid condition for patients with diabetes, lifestyle intervention approaches had not been previously evaluated for their effectiveness in treating depression. Program ACTIVE demonstrated feasibility and favorable outcomes in the treatment of depression among adults with T2DM. Participants experienced significant improvements in depression and glycemic control outcomes following the intervention, which were sustained 3 months following the completion of the intervention. A 10- to 19-point difference in the BDI-II has been found to correspond to a moderate difference in depression severity in nondiabetes samples [42]. In the current study, we observed a 10-point difference in BDI scores from baseline to POST and 3-months documenting significant change in depression severity following the intervention. These findings corresponded closely to changes in the rates of MDD as measured using the SCID psychiatric interview at baseline and follow-up assessment time points.

Participants demonstrated the ability to meet and exceed the exercise goal of 150 minutes per week in the context of mild-to-moderate depression, suggesting the appropriateness of this type of intervention for this population. Participants reported that walking was the modal type of physical activity that was performed within and beyond the community venues to which participants had been given free passes. In addition to self-reported increases in activity, we observed significant improvements in participants' ability to sustain exercise during the graded maximal exercise stress test providing further validation of self-reported exercise. Participants also reported improvements in their confidence about exercising following completion of the study. Although no changes in BMI were observed, the intervention was not designed to be a weight loss program and this outcome was expected. Finally, we observed improvements in LDL-C following the intervention, suggesting a positive impact of exercise on this cardiovascular risk factor.

Diabetes-specific quality of life, general health-related quality of life, and social support also increased following the study suggesting perceived benefits of the intervention in addition to the alleviation of mood symptoms. Participants reported improvements in their overall diabetes-related health, the impact of diabetes on quality of life, and diabetes satisfaction. Similarly, general quality-of-life scores increased in the domains of physical ability, fulfillment of role expectations, and improvement in pain-related quality of life. Participants also experienced improvements in the management of their chronic illness through personal, neighborhood, and community organization efforts. High levels of overall satisfaction and

retention provided additional evidence of the acceptability of these intervention strategies for participants.

Findings from this pilot translational study demonstrate the utility of exercise and CBT in combination for the treatment of depression and diabetes self-management. This study has a number of limitations including the lack of a control group, relatively short follow-up evaluation period, and limited sample size. Research is currently underway to further translate the components of this intervention to community mental health and exercise partnerships as well as to document the relative costs and effectiveness of the combination approach compared to standard individual therapeutic interventions.

Conclusions

Lifestyle interventions such as physical activity have the capacity to promote health in a variety of synergistic ways for adults with T2DM in addition to the well-documented benefits for those at risk for T2DM. Health care providers can make use of the findings from the DPP and Program ACTIVE to counsel patients about the multiple benefits to be gained by engaging in medically appropriate forms of physical activity in addition to referrals to mental health providers when depression has been identified. Conventional behavioral adherence strategies such as activity diaries, identification of rewards, and incremental, feasible physical activity goals that incorporate a support person for accountability are standard tools that also may be used efficiently to synergistically address mood, diabetes, and quality-of-life outcomes. Data from this pilot study document the synergistic gains that can be observed from a combination approach of exercise and CBT in both depression and diabetes outcomes.

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Table 1

Baseline demographic characteristics of Program ACTIVE participants (N = 50)

	Mean, *N*	SD, %
Age, *y* (mean, SD)	57.2	8.8
Gender		
Male	16	32.0
Female	34	68.0
Ethnicity		
White	50	100.0
Marital status		
Married/living with partner	37	74.0
Single	2	4.0
Divorced/separated	6	12.0
Widowed	5	10.0
Education		
Less than HS	3	6.7
HS diploma/GED	11	24.4
Trade school/part college	17	37.8
4-year college/post	14	31.1
Income		
0-10,000	3	6.1
11,000-20,000	5	10.2
21,000-40,000	14	28.6
41,000-60,000	13	27.0
61,000-80,000	3	6.1
81,000+	11	22.0
Home ownership	45	90.0
Work outside home	27	54.0
Dependents, *n* (mean, SD)	2.4	1.3
Difficulty making ends meet		
Hard	17	34.0
50/50	22	44.0
Easy	11	22.0
Treatment type		
Diet	5	10.0
Pills	20	40.0
Insulin injections/pump	11	22.0
Combination	14	28.0
Health insurance (yes)	46	92.0
Current PCP	50	100.0

	Mean, *N*	SD, %
Current diabetes specialist	26	53.1

ACTIVE—Appalachians Coming Together to Increase Vital Exercise; HS—high school; PCP—primary care physician.

Table 2

Program ACTIVE primary and secondary outcome variables

	Baseline		POST		3-month follow-up	
	Mean, *N*	**SD, %**	**Mean, *N***	**SD, %**	**Mean, *N***	**SD, %**
Depression outcomes						
Cases of major depressive disorder	50	100	17	34	17	34
BDI (mean, SD)	26.8	10.4	16.1	12.9[b]	16.7	13.1[b]
Diabetes outcomes						
HbA_{1c}	7.6	1.8	7.2	1.5[a]	7.3	1.3
Fasting glucose	161.0	56.0	146.3	47.0[a]	138.4	45.8[b]
Exercise outcomes						
Absolute VO_2 peak	1.4	0.4	1.5	0.4[b]	--	--
Relative VO_2 peak	14.1	3.3	15.2	3.2[b]	--	--
Exercise minutes/week (assessment)	129.5	155.0	170.6	171.5	160.8	181.4
Steps/week (assessment)	25,384.8	20,452.1	25,205.4	22,811.9	26,786.1	22,166.1
Godin activity total score	11.3	11.0	24.5[b]	22.1	23.6	20.0[b]
Exercise self-efficacy	43.9	16.2	50.8	17.3[b]	47.7	17.3
Mean minutes/week intervention	187.1	90.6	—	—	—	—
Mean steps/week intervention	30,222.9	17,683.4	—	—	—	—
Cardiovascular risk factors						
HDL-C	39.6	8.0	40.3	9.6	40.3	8.7

	Baseline		POST		3-month follow-up	
	Mean, *N*	**SD, %**	**Mean, *N***	**SD, %**	**Mean, *N***	**SD, %**
LDL-C	115.6	37.3	104.5	36.4[b]	110.2	33.4
Total cholesterol	184.1	44.3	176.9	56.1	179.2	39.9
Triglycerides	185.0	82.1	192.1	220.4	180.5	78.6
BMI	35.0	7.1	35.6	7.3	35.4	7.3
Waist-to-hip ratio	0.9	0.1	0.9	0.08	--	--
Psychosocial outcomes						
Diabetes quality-of-life total score	54.0	11.4	62.2	15.8[b]	62.1	14.8[b]
General subscale	40.1	25.4	44.2	23.9[a]	45.3	25.0[b]
Diabetes worry	58.9	18.4	61.6	23.1	63.0	20.6
Impact subscale	62.7	13.3	66.8	13.8[b]	67.1	13.8[b]
Satisfaction subscale	41.8	13.8	54.2	20.4[b]	51.1	18.7[b]
Social worry subscale	72.5	13.3	83.9	15.9	81.4	16.3
SF-36						
Physical functioning	61.2	26.3	68.7	23.0[b]	67.6	24.4[b]
Role physical	32.1	37.2	41.5	43.9[a]	42.5	44.1[a]
Bodily pain	52.7	21.9	56.6	21.3[a]	53.7	23.4
CIRS total score	75.7	16.9	82.0	20.1[b]	78.9	18.9
Community	7.3	2.8	7.8	3.4	7.5	3.0
Community organization	8.5	3.1	10.6	3.4**	9.4	3.7*

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	Baseline		POST		3-month follow-up	
	Mean, *N*	**SD, %**	**Mean, *N***	**SD, %**	**Mean, *N***	**SD, %**
Family	10.7	3.9	10.9	3.5	10.6	3.9
Health care team	16.2	4.0	16.9	4.2	17.0	4.0
Media	8.4	3.0	8.1	3.0	8.3	3.1
Neighborhood	5.3	2.2	6.9	3.2**	6.1	2.3*
Personal	12.3	3.5	13.7	4.1*	12.8	3.8
Work	7.0	6.8	7.2	7.0	7.2	6.8

ACTIVE—Appalachians Coming Together to Increase Vital Exercise; BDI—Beck Depression Inventory; BMI—body mass index; CIRS—Chronic Illness Resource Survey; HbA_{1C}—hemoglobin A_{1C}; HDL-C—high-density lipoprotein cholesterol; LDL-C—low-density lipoprotein cholesterol; POST—post-intervention.

[a] Student's *t* test baseline versus POST or 3 months: $P < 0.05$

[b] Student's *t* test baseline versus POST or 3 months: $P < 0.01$.