

Exercise Training and Quality of Life in Individuals With Type 2 Diabetes

A randomized controlled trial

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OBJECTIVE—To establish whether exercise improves quality of living (QOL) in individuals with type 2 diabetes and which exercise modalities are involved.

RESEARCH DESIGN AND METHODS—Health benefits of aerobic and resistance training in individuals with type 2 diabetes (HART-D; $n = 262$) was a 9-month exercise study comparing the effects of aerobic training, resistance training, or a combination of resistance and aerobic training versus a nonexercise control group on hemoglobin A1C (HbA_{1c}) in sedentary individuals with type 2 diabetes. This study is an ancillary analysis that examined changes in QOL after exercise training using the Short Form-36 Health Survey questionnaire compared across treatment groups and with U.S. national norms.

RESULTS—The ancillary sample ($n = 173$) had high baseline QOL compared with U.S. national norms. The QOL physical component subscale (PCS) and the general health (GH) subscale were improved by all three exercise training conditions compared with the control group condition (resistance: PCS, $P = 0.005$; GH, $P = 0.003$; aerobic: PCS, $P = 0.001$; GH, $P = 0.024$; combined: PCS, $P = 0.015$; GH, $P = 0.024$). The resistance training group had the most beneficial changes in bodily pain ($P = 0.026$), whereas physical functioning was most improved in the aerobic and combined condition groups ($P = 0.025$ and $P = 0.03$, respectively). The changes in the mental component score did not differ between the control group and any of the exercise groups (all $P > 0.05$). The combined training condition group had greater gains than the aerobic training condition group in the mental component score ($P = 0.004$), vitality ($P = 0.031$), and mental health ($P = 0.008$), and greater gains in vitality compared with the control group ($P = 0.021$).

CONCLUSIONS—Exercise improves QOL in individuals with type 2 diabetes. Combined aerobic/resistance exercise produces greater benefit in some QOL domains.

Quality of life (QOL) is a comprehensive construct that typically includes physical, emotional, and social aspects of well-being, such as physical functioning, role limitations attributable to physical or emotional problems, bodily pain, and energy level (1). Previous exercise studies in healthy subjects and individuals with cardiovascular disease (CVD) risk or other medical conditions (i.e., hypertension, chronic obstructive

pulmonary disease [COPD], cancer) have found significant improvements in QOL after exercise training (2–6). Although most of these previous studies were small and not randomized controlled trials, recent data have provided more convincing evidence of the beneficial effects of exercise on QOL. Specifically, Martin et al. (4) in a large randomized controlled trial ($N = 430$) found a significant increase in most QOL domains in response

to three different amounts of aerobic exercise training in overweight and obese postmenopausal women with high blood pressure. In addition, QOL improved with greater amounts of exercise training in a dose-dependent manner (4).

Adults with diabetes report a lower QOL than nondiabetic individuals (1,6), and exercise training may have promise for improving QOL in individuals with type 2 diabetes (4). Physical activity interventions have been shown to improve glycemic control (7,8). Given that poor glycemic control is a potential mediator between diabetes and QOL (9) changes in hemoglobin A1C (HbA_{1c}) occurring as a result of an exercise intervention may lead to improvements in QOL. To date, limited data exist regarding the effects of exercise training on QOL in sedentary adults with type 2 diabetes. Although exercise training interventions generally have shown beneficial effects on QOL in diabetic populations, many of these studies used small sample sizes, short follow-up periods, and self-directed exercise interventions rather than well-verified, supervised exercise interventions (10–13). However, two recently published trials overcame many of these limitations (14,15). Reid et al. (14) performed an analysis of QOL data from the Diabetes Aerobic and Resistance Exercise (DARE) trial, in which 218 individuals were randomized to a 22-week intervention comprising aerobic exercise only, resistance training only, combined training (aerobic and resistance), or no-exercise control condition. The authors found that mental health QOL improvements were greater in the control group compared with the resistance and the combined training groups. In addition, physical QOL improved in the resistance training group compared with the control group. Nicolucci et al. (15) examined QOL from the Italian Diabetes and Exercise Study (IDES) in which 606 individuals received either 150 min/week of supervised, progressive, mixed (aerobic and resistance) training plus exercise counseling versus counseling alone. Their results demonstrated improved QOL with increasing exercise volume.

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Thus, past studies have provided evidence for a beneficial effect of exercise training interventions on QOL in nonmedically ill and in chronically ill populations; however, the largest trials to date conflict on whether exercise benefits mental health QOL in individuals with type 2 diabetes (14,15). The current study is an ancillary analysis from the Health Benefits of Aerobic and Resistance Training in individuals with type 2 diabetes (HART-D) trial (16). In this study, we attempted to further elucidate QOL outcomes by assessing changes in all QOL subscales measured on the Short-Form 36 Health Survey (SF-36) and compared SF-36 scores to U.S. national norms. Changes in QOL from preintervention to postintervention were compared across the four exercise conditions (aerobic only, resistance only, combined aerobic and resistance, and no-exercise control). We hypothesized that the resistance training group would demonstrate the greatest improvements in physical functioning QOL subscales, and that there would be no beneficial effects of exercise interventions on mental health QOL subscales.

RESEARCH DESIGN AND METHODS

HART-D was a 9-month exercise study comparing the effects of aerobic, resistance, or a combination of both on HbA_{1c} measures in sedentary individuals with type 2 diabetes. The methods and main outcomes for HART-D have been previously published (16). A total of 262 sedentary adults with HbA_{1c} levels of 6.5–11.0% were randomized (see Supplementary Fig. 1). Diabetes diagnosis was confirmed by a medical history review. Sedentary status was defined as not participating in exercise training sessions >20 min/day on ≥3 days/week and not participating in resistance training. Exclusion criteria included a BMI >48 kg/m², younger than 30 years old or older than 75 years old, blood pressure ≥160/100 mmHg, fasting triglycerides ≥500 mg/dL, use of an insulin pump, urine protein >100 mg/dL, history of stroke, advanced neuropathy, or retinopathy, or any serious medical condition that prevented participant adherence to the study protocol or ability to exercise safely. The protocol was approved by the Institutional Review Board at Pennington Biomedical Research Center, and all participants provided written informed consent.

Study design

Participants were randomized to one of four groups: aerobic training only; resistance training only; a combination of resistance

and aerobic training (combination); or a nonexercise control group. The nonexercise control group participants were offered a weekly stretching and relaxation class and were asked to maintain their current level of activity during the 9-month study period. The primary outcome of this secondary analysis is the change in QOL measures (evaluated via the SF-36) after exercise training.

Weight and height

Weight was measured on a GSE 450 electronic scale (GSE Scale Systems; NOVI), and height was measured using a standard stadiometer. BMI was calculated as weight in kilograms divided by height in meters squared.

Quality of life

Change in QOL was evaluated using the SF-36 questionnaire (17,18). The SF-36 is a validated, self-administered questionnaire that measures QOL through the evaluation of physical functioning, role limitations attributable to physical health problems, bodily pain, general health, vitality, social functioning, emotional health, and mental health (17). QOL measures were administered at baseline and at the 9-month follow-up. Norm-based scores were used rather than raw scores, per the recommendation of the SF-36 user manual (18).

Exercise training

The exercise intervention was designed to have similar time requirements among the three exercise groups. The exercise prescription for each participant was standardized to body weight, and it was estimated that ~10 to 12 kcal/kg of body weight is equivalent to 150 min of moderate intensity exercise per week. The derivation of these calculations was based on the consensus physical activity recommendations (19). The exercise intensity for the aerobic exercise training was 50–80% of maximal oxygen consumption. The selected dose of exercise for the aerobic group was 12 kcal/kg per week and 10 kcal/kg for the combination exercise group. American College of Sports Medicine equations were used to estimate caloric expenditure rate and time required for each session (20). Participants were weighed weekly to calculate their personalized energy expenditure target. During weeks 12 and 24 only, the exercise dose was reduced by one-third to provide a recuperation week. Each session had 5-min warm-up and cool-down periods.

Participants in the resistance training group exercised 3 days/week, with each session consisting of two sets of four upper body exercises (bench press, seated row, shoulder press, and lateral pull-down), three sets of three leg exercises (leg press, extension, and flexion), and two sets of each abdominal crunches and back extensions. The combination exercise group had two resistance sessions per week, with each session consisting of one set of each of the aforementioned nine exercises. For the combination and resistance training groups, each set consisted of 10 to 12 repetitions. Once the participant was able to complete 12 repetitions for each set of exercises during two consecutive exercise sessions, the prescribed resistance (weight) was increased.

All exercise interventions were conducted at our on-site fitness center under the supervision of trained exercise interventionists. Instruction was provided on a one-on-one basis; however, participants often exercised with other study participants present because of the open environment of the fitness center. Resistance training was based on a circuit protocol, and aerobic exercise was performed primarily using the treadmill.

The stretching and relaxation conditioning was developed specifically for this trial (e.g., control group) and has not been validated. It included 45-min weekly sessions focused on increasing flexibility and reducing stress. The control group intervention was optional and was designed to be light-intensity stretching and relaxation exercises. The program was not intended to produce physiological or psychological benefits that may be observed in higher-intensity yoga exercise specifically designed to improve overall well-being. Rather, the intent of the nonexercise control condition was to provide a comparison control group that also provided a structured participation experience, thus promoting participant retention, and reduced the potential of any exposure bias between conditions (e.g., amount of time spent with study staff). Participant time spent participating in the exercise interventions was a critical component of the study design (i.e., exercise prescriptions were designed to have similar time requirements standardized to body weight); therefore, the addition of an optional stretching and relaxation class to the three exercise condition groups could have introduced study bias. Participants in the stretching and relaxation

condition group were encouraged to maintain their prerandomization level of physical activity; participants who chose to engage in an exercise program outside of the study were neither encouraged nor discouraged to continue with those efforts.

Blinding

Separate intervention and assessment teams were used, and all assessment staff members were blinded to randomized assignment of participants to intervention groups. The clinical testing and exercise training laboratories were in separate

buildings, and participants were reminded frequently to not disclose their group assignment to assessment staff.

Statistical analysis

All data were analyzed using SAS 9.2 (SAS Institute, Cary, NC). Because HART-D was designed as an efficacy study, “per-protocol” analyses limited to a subgroup of participants composed of all control participants and only the exercise group participants who met the criteria of at least 70% adherence to their exercise prescription for at least 6 months were performed. The current study modeled this

“per-protocol” study approach and, as such, chose to only include those participants who met a minimum criteria of 70% attendance to their exercise prescription for at least 6 months and had SF-36 data at baseline and follow-up ($n = 173$). Simple linear regression was implemented to test for trend across sample characteristics at baseline. Bonferonni correction was applied when testing multiple comparisons. A linear mixed-effects model for repeated measures over time was used to determine the effect of the intervention on QOL. Covariates included in the model were for age, weight,

Table 1—Baseline characteristics of participants

Characteristics	All participants (N = 173)	Control (N = 28)	Exercise Training Type		
			Resistance (N = 52)	Aerobic (N = 44)	Combination (N = 49)
Age, years, mean (SD)	57.1 (8.2)	58.1 (8.3)	58.3 (8.9)	55.1 (7.5)	56.9 (7.9)
Women, N (%)	103 (59.5)	19 (67.9)	29 (55.8)	27 (61.4)	28 (57.1)
Race/ethnicity, N (%)					
White	101 (58.4)	15 (53.6)	31 (59.6)	25 (56.8)	30 (61.2)
African American	66 (38.2)	12 (42.9)	21 (40.4)	19 (43.2)	14 (28.6)
Other	6 (3.5)	1 (3.6)	0 (0.0)	0 (0.0)	5 (10.2)
Married, N (%)	112 (64.7)	14 (50.0)	38 (73.1)	29 (65.9)	31 (63.3)
Smoking history, N (%)					
Current	8 (4.6)	1 (3.6)	3 (5.8)	1 (2.3)	3 (6.1)
Former	50 (28.9)	9 (32.1)	15 (28.9)	12 (27.3)	14 (28.6)
History of depression, N (%)	36 (20.8)	3 (10.7)	13 (25.0)	11 (25.0)	9 (18.4)
History of anxiety, N (%)	21 (12.1)	2 (7.1)	6 (11.5)	5 (11.4)	8 (16.3)
Antidepressant medication use, N (%)	32 (18.5)	6 (21.4)	11 (21.2)	7 (15.9)	8 (16.3)
QOL (SF-36 score)					
Physical					
Physical Functioning	51.6 (6.0)	51.1 (5.7)	51.4 (6.1)	51.5 (6.5)	52.1 (5.7)
Role limitations	53.6 (6.3)	53.2 (7.3)	53.5 (6.3)	53.8 (5.3)	53.6 (6.9)
Bodily pain	54.7 (7.3)	55.8 (6.7)	52.9 (7.9)	55.6 (5.7)	55.1 (8.1)
General health	50.2 (7.7)	51.2 (6.3)	49.7 (8.3)	49.8 (7.7)	50.6 (7.9)
Component score	51.8 (5.8)	51.2 (5.9)	50.9 (5.9)	52.0 (5.0)	52.7 (6.3)
Mental					
Social functioning	54.3 (6.0)	54.2 (5.6)	54.9 (4.3)	54.4 (5.7)	53.6 (7.9)
Role limitations	53.1 (5.9)	54.6 (2.8)	52.9 (7.1)	53.4 (4.1)	52.1 (6.9)
Vitality	52.9 (8.5)	53.7 (8.0)	52.6 (8.7)	54.3 (8.9)	51.5 (8.4)
Mental health	55.3 (6.3)	57.6 (4.2)	55.6 (5.7)	55.0 (6.9)	53.7 (7.0)
Component score	54.5 (6.4)	56.5 (4.5)	54.9 (6.2)	54.8 (5.9)	52.6 (7.5)
Biometric data					
HbA _{1c} , %	7.6 (1.0)	8.0 (1.5)	7.6 (0.9)	7.4 (0.9)	7.5 (0.9)
Fasting glucose, mg/dL	150.6 (36.6)	163.0 (45.5)	154.3 (38.8)	142.1 (29.3)	148.9 (34.5)
Weight, kg	98.3 (19.3)	96.9 (20.4)	99.0 (16.8)	95.7 (18.7)	100.5 (21.8)
BMI	34.7 (6.0)	34.5 (6.3)	34.8 (5.6)	33.7 (5.8)	35.6 (6.5)
Waist circumference, cm					
Men	116.2 (14.8)	115.3 (16.9)	114.3 (13.0)	115.4 (14.9)	119.4 (15.7)
Women	109.7 (12.7)	108.4 (12.9)	108.6 (11.2)	108.8 (13.3)	112.4 (13.3)

Data presented as mean (SD) unless otherwise stated. BMI was calculated as weight in kilograms divided by height in meters squared. To convert fasting glucose to mmol/L, multiply by 0.0555. No significant differences in demographic characteristics at baseline were revealed across the different treatment conditions.

ethnicity, antidepressant use, and marital status. Results are presented as adjusted least-square means with 95% CIs. In addition, we used z-scores to compare QOL measures in our study sample to U.S. normative SF-36 data in individuals with type 2 diabetes (21). Statistical significance was set at $P \leq 0.05$ (two-tailed) throughout.

RESULTS

Participant characteristics

A total of 2,421 adults were screened for possible participation in the study and 262 participants were randomized. The main trial was completed by 243 participants. The QOL assessment materials were added to the protocol soon after the study was initiated because of a delay in obtaining copyright permissions, thus resulting in QOL data for 173 participants.

Baseline characteristics of the analytic sample are presented in Table 1. The mean age of participants was 57.1 (SD 8.2) years. The majority of participants were female (59.5%), White (58.4%), and married (64.7%). Few current smokers participated in the trial (4.6%). Antidepressant medication was used by 18.5% of the participants, and a history of depression and anxiety was reported by 20.8% and 12.1% of participants, respectively. Mean BMI at study entry was 34.7 (SD 6.0) kg/m^2 and the mean $\text{HbA}_{1\text{c}}$ was 7.6% (SD 1.0%). These characteristics were similar to those of the main study cohort, and no significant differences in demographic characteristics at baseline were revealed across the different treatment conditions.

United States population norms for individuals with type 2 diabetes and baseline means for the current study sample on SF-36 subscales, matched by

age, gender, and age by gender, were compared using z-scores. The HART-D sample had higher mean SF-36 QOL scores on all subscales.

Baseline HART-D SF-36 mental component and physical component summary scores are presented for different subgroups in Table 2. Individuals with $\text{BMI} > 40 \text{ kg}/\text{m}^2$ had lower physical component scores than those with BMI between 25 and 35 kg/m^2 (all $P < 0.05$). Individuals who were not married had lower mental component summary scores, as did individuals using antidepressants ($P < 0.05$). Unexpectedly, individuals with lower $\text{HbA}_{1\text{c}}$ reported worse functioning on mental component subscales ($P < 0.05$).

SF-36 change: Physical health QOL component score and subscales

Figure 1 shows change from pre-exercise to postexercise intervention for the SF-36 physical health QOL component score and subscales. All three exercise condition groups had greater improvements than the control group (resistance $P = 0.005$, aerobic $P = 0.001$, combined $P = 0.015$). In addition to all three exercise condition groups having greater improvements than the control group on the physical component score; the general health subscale also improved more for all three exercise conditions compared with the control condition (resistance $P = 0.003$, aerobic $P = 0.024$, combined $P = 0.024$). On the physical functioning subscale, the aerobic training condition group and the combined training condition group had greater improvements than the control condition group ($P = 0.025$ and $P = 0.03$, respectively). The bodily pain subscale was higher postintervention in all condition groups; however, the resistance training group reported a smaller increase in bodily pain compared with the control condition group ($P = 0.026$).

SF-36 change: Mental health QOL component score and subscales

Changes from preintervention to postintervention for the SF-36 mental health QOL component score and subscales are shown in Fig. 2. The changes in the mental component summary score did not differ between the control group and any of the exercise groups (all $P > 0.05$). However, greater improvements in the mental component summary score were found in the combined training condition group relative to the aerobic

Table 2—Quality of life by subgroup

Baseline category	N	Physical component score, mean (SD)	Mental component score, mean (SD)
Ethnicity			
White	101	52.0 (5.9)	53.7 (6.8)
African American	66	51.0 (5.8)	55.5 (5.8)
Other	6	55.4 (1.7)	55.6 (4.6)
Age, years			
35–54	63	51.6 (5.7)	54.0 (5.9)
55–64	80	52.2 (5.9)	54.5 (6.5)
65+	30	51.1 (5.9)	55.5 (7.1)
BMI range			
18.5 to <25	9	54.6 (5.5)	55.0 (6.0)
25 to <30	31	53.2 (4.7)§	53.5 (6.2)
30 to <35	50	52.8 (5.4)§	55.1 (6.1)
35 to <40	45	51.2 (5.0)	54.5 (6.1)
40 or more	38	49.3 (7.1)§	54.2 (7.6)
Smoking status			
Never	115	51.3 (6.3)	54.4 (6.4)
Former	50	52.9 (4.6)	54.4 (6.9)
Current	8	52.1 (3.8)	55.7 (3.9)
Marital status			
Not married	52	51.7 (6.3)	52.8 (7.7)*
Married	112	51.9 (5.4)	55.2 (5.6)
Antidepressant use			
No	141	52.2 (5.5)	55.5 (5.0)†
Yes	32	50.0 (6.7)	49.9 (9.5)
HbA_{1c}, % category			
<7.0	58	51.3 (6.3)	52.7 (7.9)‡
≥7.0	115	52.0 (5.5)	55.4 (5.3)

*Individuals who were not married had lower mental component summary scores compared with those who were married ($P < 0.05$). †Individuals using antidepressants had lower mental component summary scores compared with those not using antidepressants ($P < 0.05$). ‡Individuals with $\text{HbA}_{1\text{c}} < 7.0\%$ had a significantly lower mental component score than those with $\text{HbA}_{1\text{c}} > 7.0\%$ ($P < 0.05$). §Individuals with $\text{BMI} > 40 \text{ kg}/\text{m}^2$ had a lower physical component score than those with BMI between 25 and 35 kg/m^2 ($P < 0.05$).

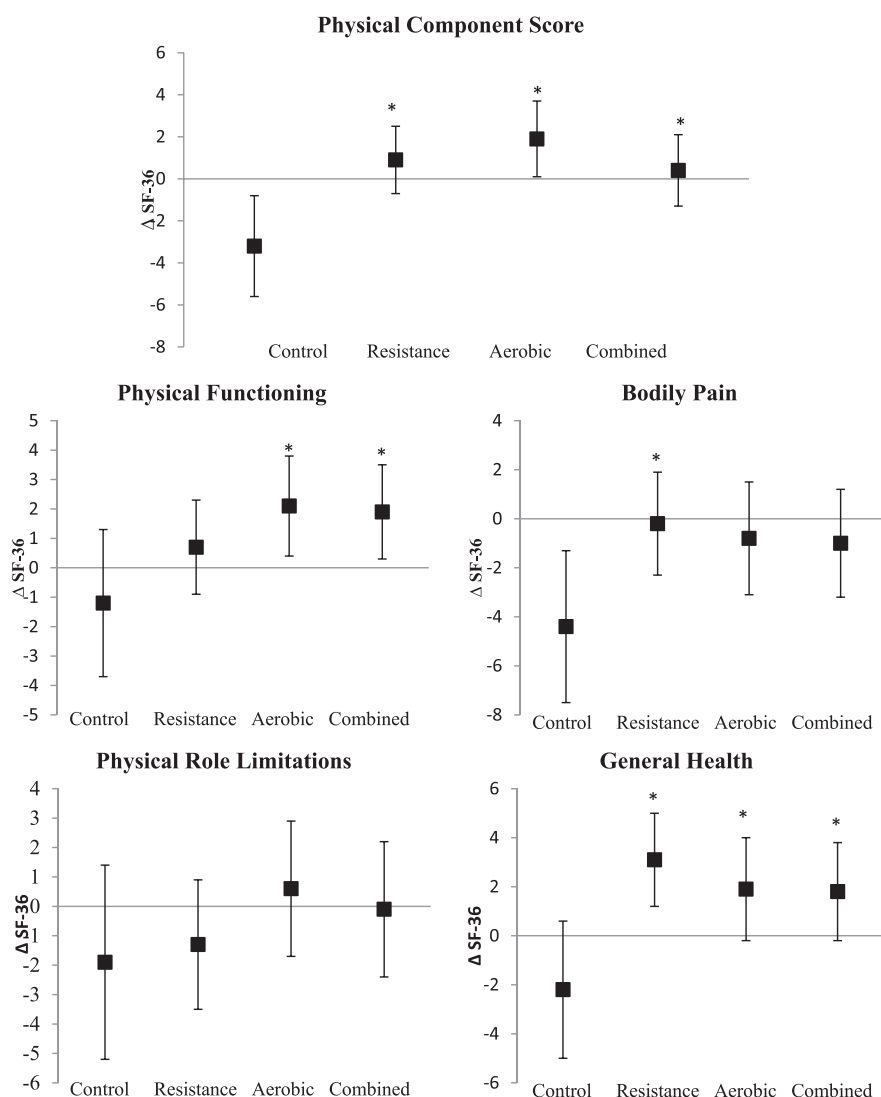


Figure 1—SF-36 physical health component and subscale change scores for aerobic, resistance, combined, and no-exercise control groups. Mean change (least-squares means \pm 95% CI) in SF-36 scores for the control and exercise groups. Differences in scores across groups were tested using mixed models with adjustment for age, weight, ethnicity, antidepressant use, and marital status. * $P < 0.05$ when compared to the control group.

training condition group ($P = 0.004$). The combined training also was associated with gains relative to the aerobic training on the vitality ($P = 0.031$) and mental health ($P = 0.008$) subscales. The only mental health QOL subscale for which an exercise group benefited relative to the control group was the vitality subscale. Specifically, the combined training group had greater gains in vitality than the control group ($P = 0.021$).

CONCLUSIONS—The primary finding of the current study is that exercise training interventions improved physical health QOL in individuals with type 2 diabetes mellitus regardless of training modality (aerobic, resistance, or combined). In

addition, although the effects of the exercise training on mental health QOL were limited, the improvements in mental QOL often favored combined aerobic and resistance training. Overall, our data suggest that exercise training has a beneficial effect on QOL in individuals with type 2 diabetes, who generally report reduced QOL compared with individuals without diabetes.

In the current study, all exercise groups reported greater improvements in overall physical health QOL (i.e., physical component summary) compared with the control group. These results can be contrasted to the DARE trial (14) and IDES study (15), which previously have investigated the effect of different

exercise training modalities in a randomized control trial of comparable size and design as HART-D (16). In the DARE trial, Reid et al. (14) found improvements in physical QOL with resistance training but not with aerobic or combined aerobic and resistance training. Differences in study design between these two studies may have contributed to the discrepancy. For example, the training intervention used by Reid et al. lasted five and one-half months, compared with 9 months for the current study, suggesting that it may require a greater amount of time of exercise training before improvements in QOL become apparent. This hypothesis is supported by the IDES study (15), which found a beneficial effect on physical QOL during a 12-month intervention. Additionally, in the study by Reid et al., the combined exercise intervention group spent twice as long exercising per week as the aerobic or resistance intervention condition group, whereas in the current study the amount of time exercising was held constant across condition groups. In the IDES study (15), the authors noted that significant improvement in physical QOL occurred only when exercise volume increased >17.5 metabolic equivalents per $h^{-1}/week^{-1}$. We did not measure dose response for our intervention but similarly found benefits in physical QOL regardless of treatment modality. The findings of the current study are supported by data from large randomized trials of individuals without diabetes (2–5) and trials of individuals with type 2 diabetes showing improvements in QOL after an exercise training intervention (6,10–13,15,22).

There are other notable results regarding physical health QOL from the current study. Reported bodily pain was higher postintervention compared with preintervention in all condition groups, including the control condition group. It is possible that increases in bodily pain in the exercise condition groups were related to muscle soreness caused by the exercise training. Of note, resistance training, but not aerobic or combined training, appeared to mitigate the increase in pain that participants experienced over the course of the study. In contrast, aerobic and combined training had the most beneficial effect regarding the physical functioning subscale, which measures participants' functioning in physical activities required for daily living.

No differences were found in the mental health QOL summary score for

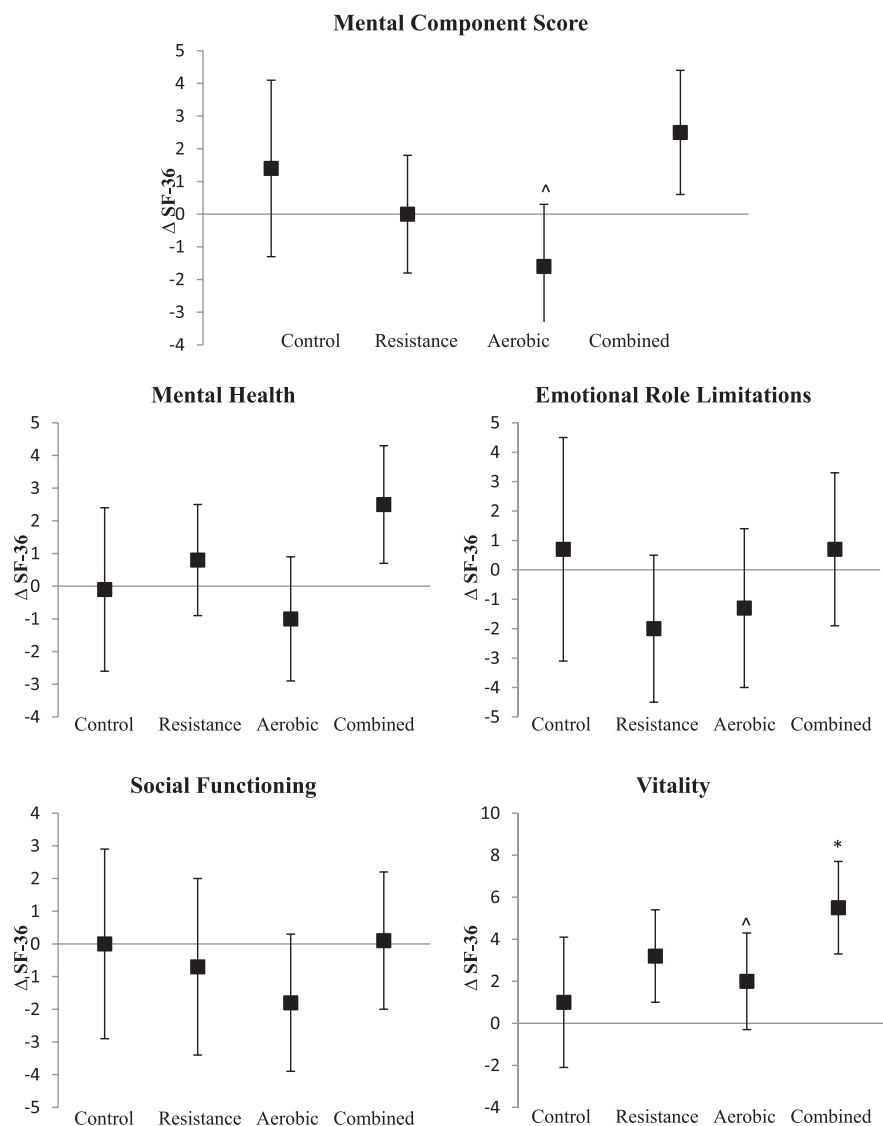


Figure 2—SF-36 mental health component and subscale change scores for aerobic, resistance, combined, and no-exercise control groups. Mean change (least-squares means \pm 95% CI) in SF-36 scores for the control and exercise groups. Differences in scores across groups were tested using mixed models with adjustment for age, weight, ethnicity, antidepressant use, and marital status. * $P < 0.05$ when compared to the control group. $\wedge P < 0.05$ when compared to combined group.

any of the exercise groups compared with the control group. These results are different from those found by Reid et al. (14), who unexpectedly found that mental QOL improved most in the nonexercise control group relative to the three exercise intervention groups. These results also differ from those of Nicolucci et al. (15), who found benefits in mental health QOL with exercise. In the current study, vitality was the only mental health QOL subscale for which any exercise group showed improvements relative to the control condition group, with the combined aerobic and resistance training condition resulting in increased vitality

ratings compared with the control condition. The lack of improvements in mental QOL for the exercise groups compared with the control group on all subscales except vitality is notable and contrasts with studies of nondiabetic populations showing more widespread mental QOL gains with exercise. It is possible that the baseline level of mental QOL impacted our results. The mental health QOL for our study sample was higher than average on initiation of the program, and it is possible that individuals with lower baseline mental QOL receive more benefit from exercise. Additionally, it may be that longer exercise programs are necessary to

improve mental QOL. It is notable that of the two comparable studies discussed (14,15), the shorter study, which was 5.5 months (14), found mental QOL decreases with exercise whereas the longer study, which was 12 months (15) reported mental health QOL gains. Our study, of intermediate length (9 months), found minimal mental health QOL changes.

These results have significant clinical implications. For a number of QOL measures, the combined exercise training condition appeared to have more beneficial effects on mental QOL compared with the aerobic condition. For example, the combined group had greater increases in the mental component summary and the mental health subscale compared with the aerobic group. Given that the combined exercise condition was the only condition to significantly improve HbA_{1c} in the main outcomes study (16), and given that all conditions were similarly effective in improving physical health QOL, these disparate effects of exercise modality on mental health QOL support recommendations for individuals with type 2 diabetes to adopt exercise programs with combined aerobic and resistance training. At the same time, these results demonstrate that regardless of the exercise modality, a moderately intensive exercise program consistent with public health recommendations in sedentary individuals with diabetes is likely to result in improved QOL, and that exercise interventions should be further integrated into standard care for individuals with diabetes.

This study has certain limitations. The participants in the current study had higher baseline QOL compared with normative U.S. samples of individuals with diabetes. In general, the diabetes in HART-D participants was relatively well-controlled, with average HbA_{1c} levels of 7.6%. Therefore, it is possible that an exercise intervention could have a more substantial impact on QOL in individuals with lower baseline QOL and more poorly controlled diabetes.

A potential concern is that the control condition (e.g., stretching and relaxation group) could have biased the outcomes by providing a therapeutic effect on QOL. The control condition was designed to be light in intensity, thus not reaching any therapeutic level to trigger improvements in physiological or emotional health outcomes. Because of low attendance in the stretching and relaxation class (22.7%), it is reasonable to assume that this condition

did not have any significant effect on QOL as a group.

This study also has notable strengths. We studied a large sample that included substantial African American representation, and we used a carefully controlled, randomized study design. In addition, the exercise intervention was controlled for exercise dose, and all exercise groups participated in a similar amount of training.

In conclusion, the current study provides evidence that adults with type 2 diabetes mellitus are likely to benefit from adopting an exercise training regimen regardless of exercise training modality (aerobic, resistance, or a combination of both). Given the overall beneficial effects of combined training on many aspects of QOL and the previously reported benefits of combined training on glycemic control, a combined aerobic and resistance approach is particularly worthy of further study.

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V.H.M. contributed to the study concept and design, acquisition of data, critical revisions of the manuscript for important intellectual content, and administrative, technical, and material support; analyzed and interpreted data, drafted the manuscript, and conducted statistical analyses. M.A.M. contributed to the study concept and design, contributed critical revisions of the manuscript for important intellectual content, analyzed and interpreted the data, drafted the manuscript, and conducted statistical analysis. M.M.B. analyzed and interpreted the data, drafted the manuscript, conducted statistical analyses, and contributed critical revisions of the manuscript for important intellectual content. N.M.J. contributed to acquisition of data, critical revisions of the manuscript for important intellectual content, and study supervision. D.L.S. contributed to study concept and design and critical revisions of the manuscript for important intellectual content; conducted statistical analyses, and drafted the manuscript. K.K. contributed to acquisition of data and critical revisions of the manuscript for important intellectual content. M.N.H. contributed to acquisition of data, critical revisions of the manuscript for important intellectual content, administrative, technical, and material support; and study supervision. W.D.J. analyzed and interpreted the data, contributed critical revisions of the manuscript for important intellectual content, and conducted statistical analyses. C.P.E. contributed to acquisition of data, critical revisions of the manuscript for

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