Effects of Moderate- Versus High-Intensity Exercise Training on Physical Fitness and Physical Function in People With Type 2 Diabetes: A Randomized Clinical Trial

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Background. Exercise training is effective for improving physical fitness and physical function in people with type 2 diabetes. However, limited research has been conducted on the optimal exercise training intensity for this population.

Objective. The primary study objective was to investigate the effects of moderate-versus high-intensity exercise training on physical fitness and physical function in people with type 2 diabetes.

Design. This was a randomized clinical trial.

Setting. The setting was a university campus.

Participants. Twenty-one people with type 2 diabetes were randomly allocated to receive either moderate-intensity training (MOD group) or high-intensity training (HIGH group).

Intervention. The MOD group performed resistance training at an intensity of 75% of the 8-repetition maximum (8-RM) and aerobic training at an intensity of 30% to 45% of the heart rate reserve (HRR). The HIGH group performed resistance training at an intensity of 100% of the 8-RM and aerobic training at an intensity of 50% to 65% of the HRR.

Measurements. Muscle strength (peak torque [newton-meters]), exercise capacity (graded exercise test duration [minutes]), and physical function (Patient-Specific Functional Scale questionnaire) were measured at baseline and 3 months later. Acute exercise-induced changes in glucose levels were assessed immediately before exercise, immediately after exercise, and 1 hour after exercise during the first exercise training session.

Results. Although both groups showed improvements in physical fitness and physical function, the between-group effect sizes were not statistically significant (exercise capacity estimated marginal mean [EMM] difference = 2.1, 95% confidence interval [95% CI] = −0.2, 4.5; muscle strength EMM difference = 20.8, 95% CI = −23.3, 65.0; and physical function EMM difference = 0.1, 95% CI = −0.6, 0.9). Mean percent changes in glucose levels measured immediately before exercise and immediately after exercise, immediately before exercise and 1 hour after exercise, and immediately before exercise and 1 hour after exercise for the MOD group were −11.4%, −5.0%, and −15.8%, respectively; those for the HIGH group were −21.5%, 7.9%, and −15.3%, respectively.

Limitations. Sample size, lack of outcome assessor masking, and physical function measurement subjectivity were limitations.

Conclusions. Moderate- and high-intensity exercise training, as defined in this study, may lead to similar improvements in physical fitness and physical function in people with type 2 diabetes.
Type 2 diabetes is a chronic metabolic disease characterized by hyperglycemia resulting from insulin resistance and impaired insulin secretion. Type 2 diabetes has multiple major complications, including cardiovascular disease. People with type 2 diabetes have a higher incidence of cardiovascular disease-related early death than people without type 2 diabetes. Another complication of type 2 diabetes is loss of physical function. The findings of Sinclair et al suggested that people with type 2 diabetes are 2 times more likely to experience loss of physical function than people without type 2 diabetes. People with type 2 diabetes also have lower levels of physical fitness—specifically, muscle strength and exercise capacity—and experience accelerated loss of muscle strength. Deficits in muscle strength and exercise capacity are relevant for people with type 2 diabetes because such deficits have been associated with physical disability and increased risk of mortality, respectively.

The clinical management of type 2 diabetes consists of nutrition therapy, pharmacological therapy, and exercise. The American Diabetes Association (ADA), American College of Sports Medicine (ACSM), and American Heart Association (AHA) have published position statements recommending the use of exercise as an intervention for type 2 diabetes. Previous studies provided supportive evidence for the use of prescribed exercise programs in the treatment of type 2 diabetes. However, dosing variables, such as intensities, of these exercise programs have varied. Furthermore, the ADA, ACSM, and AHA have recommended a spectrum of exercise training intensities for people with type 2 diabetes. Clinical trials to compare the effects of different exercise training intensities for people with type 2 diabetes should be performed to more precisely identify the intensities of exercise training needed to achieve optimal outcomes.

Evidence has suggested that aerobic training and resistance training at various intensities can be beneficial for people with type 2 diabetes. Dunst et al reported that resistance training at an intensity of 50% to 85% of the 1-repetition maximum resulted in improved muscle strength in people with type 2 diabetes. Sigal et al found that people with type 2 diabetes who performed aerobic training at an intensity of 75% of the heart rate maximum combined with resistance training at an 8-repetition maximum (8-RM) experienced an increase in muscle strength and exercise capacity. Hansen et al compared aerobic training at a heart rate correlating with 50% of peak oxygen uptake and aerobic training at a heart rate associated with 75% of peak oxygen uptake in people with type 2 diabetes and observed similar improvements in exercise capacity. Previous trials also showed that people who had type 2 diabetes and participated in resistance training could experience improvements in physical function.

A randomized clinical trial comparing different intensities of exercise training in people with type 2 diabetes would be clinically important because it could provide clinicians with evidence for precise prescribed intensities of exercise training needed to achieve optimal outcomes. Our research hypothesis was that high-intensity exercise training would be superior to moderate-intensity exercise training for improving physical fitness and physical function in people with type 2 diabetes.

The clinical management of type 2 diabetes consists of nutrition therapy, pharmacological therapy, and exercise. The American Diabetes Association (ADA), American College of Sports Medicine (ACSM), and American Heart Association (AHA) have published position statements recommending the use of exercise as an intervention for type 2 diabetes. The findings of this study indicate that combined resistance and aerobic training at moderate and high intensities may have similar effects for improving physical fitness and physical function.

Patients with type 2 diabetes can exercise at either moderate or high intensities and may experience similar results.
diabetes. The purpose of this randomized clinical trial was to investigate the effects of moderate- versus high-intensity exercise training on physical fitness and physical function in people with type 2 diabetes. An additional aim was to investigate whether moderate-intensity exercise training and high-intensity exercise training had different effects on acute exercise-induced changes in glucose levels in this population.

**Method**

**Design Overview**

This investigation was a randomized clinical trial of the effects of moderate- versus high-intensity exercise training on physical fitness and physical function in people with type 2 diabetes. Participants were randomly allocated to either a moderate-intensity exercise training group (MOD group) or a high-intensity exercise training group (HIGH group). Both groups underwent combined aerobic training and resistance training at different intensities. Physical fitness and physical function outcomes were assessed at baseline and 3 months later. Plasma glucose levels were measured immediately before exercise, immediately after exercise, and 1 hour after exercise during the first exercise training session.

**Setting and Participants**

This randomized clinical trial was conducted at the University of Central Arkansas, Conway, Arkansas, from September 2011 to August 2012. Participants who were 18 to 69 years of age were recruited from the central Arkansas geographic area by posting study recruitment flyers at local medical clinics and community centers, by making study recruitment announcements at the University of Central Arkansas, and by word of mouth. All participants met ADA diagnostic criteria for type 2 diabetes, which are symptoms of type 2 diabetes plus a casual (see below) plasma glucose level of 200 mg/dL or greater, a fasting plasma glucose level of 126 mg/dL or greater, a plasma glucose level of 200 mg/dL or greater during a 2-hour oral glucose tolerance test with a 75-g glucose load, or a glycated hemoglobin level of 6.5% or greater. Casual was defined as any time of day without regard to the time since the last meal. Symptoms of type 2 diabetes include polyuria, polydipsia, and unexplained weight loss. Fasting was defined as no caloric intake for at least 8 hours. Furthermore, a physician provided written confirmation that each participant was medically stable enough to participate in this investigation.

A detailed health history was collected from each person who volunteered to participate in this study. People with a history of a medical condition identified by the AHA as an absolute contraindication to exercise testing were excluded from this study. Furthermore, people with angina (stable or unstable), uncontrolled hypertension, proliferative retinopathy, severe peripheral neuropathy, nephropathy, autonomic neuropathy, a history of coronary artery disease, or a history of myocardial infarction; people taking a β-blocker drug; or people who had a physical impairment that precluded aerobic or resistance training were excluded from this study. Also, people involved in resistance training or aerobic training within 3 months of the beginning of this investigation were excluded. Participants were required to sign a written informed consent form.

**Randomization and Interventions**

Random allocation was performed with a computer-generated randomized sequence of group allocation created before study enrollment. As each participant consecutively entered this randomized clinical trial, he or she was randomly allocated to either the MOD group or the HIGH group according to the computer-generated sequence of group allocation. The randomization sequence was not concealed from the investigator who was responsible for assigning participants to groups. The likelihood of bias introduced by unconcealed randomization was reduced by enrollment of consecutive participants. The investigators who assessed the outcomes were not unaware of group allocation. The investigators who delivered the interventions could not be unaware of group allocation because of the nature of the interventions. The participants were unaware of group assignment because they were not informed of which exercise training intensity (moderate or high) they received. Furthermore, the investigators who performed the statistical analyses were not unaware of group assignment.

For all participants, exercise training consisted of a prescribed exercise program involving combined resistance training and aerobic training as recommended by the ADA, ACSM, and AHA for people with type 2 diabetes. In an effort to address participant safety, we chose isotonic resistance machines instead of free weights for resistance training. Specifically, resistance training consisted of chest press, seated row, leg press, and seated isolated knee extension exercises (Cybex International, Medway, Massachusetts). Aerobic training consisted of walking on a treadmill (TRUE Fitness Technology, St Louis, Missouri).

For prescribing the intensities of exercise training, we followed the AHA recommendations for moderate and high intensities of exercise training for people with type 2 diabetes, with the MOD group receiving the moderate intensity and the HIGH group receiving the high intensity.
 Dosage parameters for exercise training include intensity, volume, frequency, duration, and rate of progression. In this study, intensity was defined as the training resistance (weight) during resistance training and as the target heart rate during aerobic training. Volume was defined as the number of sets and repetitions assigned for each resistance training session and the length of time prescribed for each aerobic training session. Frequency was defined as the number of days per week assigned for exercise training, and duration was defined as the number of months prescribed for the exercise training program. Rate of progression was defined as the rate at which the resistance was increased during resistance training and the rate at which the speed or percent grade of the treadmill was increased during aerobic training, on the basis of the target heart rate. All of these dosage parameters were the same for the MOD group and the HIGH group, except for intensity.

Both groups performed resistance training on 2 nonconsecutive days per week for 3 months. During the first exercise training session of each week, both groups underwent 8-RM testing on each piece of resistance training equipment. Each participant in the MOD group was prescribed 4 sets of up to 8 repetitions of each resistance training exercise at 75% of his or her respective 8-RM. The MOD group performed 4 sets of up to 8 repetitions at 75% of the 8-RM on 100% of the completed exercise training days. For each participant in the HIGH group, 4 sets of up to 8 repetitions of each resistance training exercise at 100% of his or her respective 8-RM were prescribed. The HIGH group performed 4 sets of up to 8 repetitions at 100% of the 8-RM on 100% of the completed exercise training days. On days on which the 8-RM test was performed, the 8-RM test was counted as 1 set.

For both groups, the rate of progression was based on the prescribed percentage of the weekly established 8-RM. The rest period between sets of exercise was 1 to 3 minutes for both groups.

In addition to resistance training, both groups performed aerobic training on 3 days per week, either consecutive or nonconsecutive, for 3 months. Each participant in the MOD group walked on a treadmill for 20 minutes at a speed and percent grade in a target heart rate range of 30% to 45% of his or her respective heart rate reserve, calculated with the formula of Karvonen et al.\(^28\) The MOD group performed aerobic training in a heart rate range of 30% to 45% of the heart rate reserve on 95% of the completed exercise training days and performed 20 minutes of aerobic training on 100% of the completed exercise training days. Each participant in the HIGH group walked on a treadmill for 20 minutes at a speed and percent grade in a target heart rate range of 50% to 65% of his or her respective heart rate reserve, calculated with the formula of Karvonen et al.\(^28\) The HIGH group performed aerobic training in a heart rate range of 50% to 65% of the heart rate reserve on 100% of the completed exercise training days and performed 20 minutes of aerobic training on 100% of the completed exercise training days. For both groups, the speed or percent grade of the treadmill was progressively increased as tolerated during the next training day and each subsequent training day, on the basis of the prescribed target heart rate. Participants performed aerobic training on the same days as resistance training and on an additional day so that aerobic training was performed on 3 days per week. During aerobic training, heart rate was constantly measured with a wireless heart rate monitor (Polar Electro, Inc, Lake Success, New York). A summary of the exercise training prescriptions for both groups is shown in Table 1.

Participants in both groups were supervised during each exercise training session by an investigator or a research assistant. Exercise training was conducted at a fitness center on the campus of the University of Central Arkansas that contained the resistance training equipment and treadmills needed to complete the prescribed exercise program. Before beginning the exercise program, participants became familiarized with the use of the resistance training equipment and treadmills. Supervisors carried glucose tablets in case participants experienced signs of hypoglycemia during exercise training. In an effort to prevent hypoglycemia, any participant who had a blood glucose level of less than 100 mg/dL before an exercise session consumed glucose tablets until a blood glucose level of at least 100 mg/dL was reached.\(^13\) Participants were instructed to immediately inform supervisors if they experienced any unusual symptoms during exercise training and to consult a physician if needed. Participants were instructed to refrain from exercise training and to avoid changing their physical activity levels outside this study, and all participants reported adhering to these instructions.

Outcome Measures

Physical fitness outcome measures were muscle strength and exercise capacity. Muscle strength was measured with isokinetic dynamometry. Isokinetic dynamometry testing of the knee extensor muscles on the dominant side of the body was performed with a Biodex System 4 isokinetic dynamometer (Biodex Medical Systems Inc, Shirley, New York). The dominant side was defined as the side on which the lower extremity that the participant reportedly used for kicking was located. Partic-
Participants were tested concentrically at 60°/s through a range of motion of 90 degrees of knee flexion to full knee extension and positioned in accordance with the recommendations of the manufacturer of the dynamometer. Before testing, familiarization consisting of 1 repetition at 50%, 75%, and 100% of the maximum effort needed to produce a maximum contraction at 60°/s was completed (a total of 3 repetitions). After a 2-minute rest period, participants performed 3 repetitions at 100% of the maximum contraction effort at 60°/s. During each repetition, participants were given verbal instructions to exert the maximum effort. Also, each participant viewed his or her torque production curve on a computer monitor during each repetition and was instructed to attempt to produce a higher torque during each subsequent repetition while viewing the curve. The highest peak score of the 3 repetitions was recorded. Muscle strength was expressed as peak torque (newton-meters). The results of previous research indicated that isokinetic dynamometry testing is reliable and is a standard for measuring muscle strength.29,30 Exercise capacity was quantified with a graded exercise test. The graded exercise test was conducted with a modified Bruce treadmill protocol31,32 as described by Taylor et al.33 The graded exercise test was continued until the participant either achieved 85% of the age-predicted maximum heart rate \( [208 - (0.7 \times \text{age})]^{34} \) or voluntarily stopped the graded exercise test, whichever endpoint occurred first. The heart rate (beats per minute) of each participant was constantly measured throughout the graded exercise test with a wireless heart rate monitor (Polar Electro Inc). The blood pressure of each participant was also monitored during each stage of the graded exercise test. The graded exercise test duration was constantly measured with a digital timer. Exercise capacity was defined as the total duration (minutes) of the graded exercise test. The findings of previous research suggested that graded exercise testing, as described in this study, is reliable and is a standard for measuring exercise capacity.27,33

Physical function was measured with the Patient-Specific Functional Scale (PSFS) questionnaire.35 In accordance with the procedures for administering the PSFS, as described by Stratford et al,35 each participant was asked to identify up to 5 important activities that he or she was unable to perform or had difficulty performing. Next, each participant was asked to rate the level of difficulty in performing each activity using a scale from 0 to 10 (0 = unable to perform, 10 = able to perform). Instructions for administering the PSFS, a copy of the questionnaire, and data pertaining to its reliability and validity have been published.35–38 The reliability and validity of the PSFS specifically in people with type 2 diabetes have not been investigated.

On the first exercise training day, data also were collected to assess acute exercise-induced changes in glucose levels. Capillary plasma glucose levels (mg/dL) were measured

<p>| Table 1. Summary of Exercise Training Prescriptionsa |
|---------------------------------|---------------------------------|---------------------------------|</p>
<table>
<thead>
<tr>
<th>Type of Training Parameter</th>
<th>Moderate-Intensity Exercise Training Group</th>
<th>High-Intensity Exercise Training Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance Intensity</td>
<td>75% of 8-RM</td>
<td>100% of 8-RM</td>
</tr>
<tr>
<td>Volume</td>
<td>4 sets of up to 8 repetitions</td>
<td>4 sets of up to 8 repetitions</td>
</tr>
<tr>
<td>Frequency</td>
<td>2 d/wk</td>
<td>2 d/wk</td>
</tr>
<tr>
<td>Duration</td>
<td>3 mo (12 wk)</td>
<td>3 mo (12 wk)</td>
</tr>
<tr>
<td>Rate of progression</td>
<td>Resistance increased on the basis of the prescribed percentage of the weekly established 8-RM</td>
<td>Resistance increased on the basis of the prescribed percentage of the weekly established 8-RM</td>
</tr>
<tr>
<td>Aerobic Intensity</td>
<td>30%–45% of heart rate reserve</td>
<td>50%–65% of heart rate reserve</td>
</tr>
<tr>
<td>Volume</td>
<td>20 min</td>
<td>20 min</td>
</tr>
<tr>
<td>Frequency</td>
<td>3 d/wk</td>
<td>3 d/wk</td>
</tr>
<tr>
<td>Duration</td>
<td>3 mo (12 wk)</td>
<td>3 mo (12 wk)</td>
</tr>
<tr>
<td>Rate of progression</td>
<td>Treadmill speed or grade increased as tolerated each training day on the basis of the prescribed percentage of heart rate reserve</td>
<td>Treadmill speed or grade increased as tolerated each training day on the basis of the prescribed percentage of heart rate reserve</td>
</tr>
</tbody>
</table>

*a 8-RM = 8-repetition maximum.*
Moderate- Versus High-Intensity Exercise Training in People With Type 2 Diabetes

immediately before exercise training, immediately after exercise training, and 1 hour after exercise training on the first day of exercise training. During the 1-hour postexercise period, participants were positioned in a chair and did not consume any food or drink, except water as requested. Capillary plasma glucose levels were measured by taking a sample of blood with the fingerstick technique. The plasma glucose concentration was assessed with a Freestyle Glucometer (Abbott Diabetes Care Inc, Alameda, California) in accordance with the recommendations of the manufacturer.

Additional outcomes of this study were participant adherence and adverse events. The investigator or research assistant who supervised each group recorded the date of each completed exercise training session and the length of time spent during each exercise training session; these data were used to assess each group’s adherence to the exercise program. Total exercise time was defined as the total time spent exercise training during this study. Supervisors also monitored participant adherence to the prescribed exercise training program variables (including intensity) during every exercise training session. Data about adverse events were collected by direct observation during supervised exercise training sessions and by asking the participants about any potential adverse events outside the supervised sessions.

Statistical Analysis
To retain data from all randomly allocated participants, we performed an intention-to-treat analysis. Postintervention physical fitness outcomes were missing for only 1 participant in the HIGH group. The outcomes for glucose levels immediately after exercise and 1 hour after exercise were missing for only 1 participant in the MOD group. Multiple imputation was used to analyze missing outcomes. Five possible values for each missing outcome were generated by multiple linear regression with intervention group as the covariate, and the final imputed value was the mean of the 5 possible values. Multiple imputation was performed with NORM Version 2 for Windows (NORM=multiple imputation of incomplete multivariate data under a normal model; The Methodology Center, Pennsylvania State University, University Park, Pennsylvania). An analysis of variance was used to investigate any possible differences in baseline characteristics and adherence between the groups. The adherence of both groups to the exercise program was expressed as the total number of training days completed by each participant (out of the prescribed number of training days) and the total exercise time during the 3-month exercise program. A general linear model was used to analyze between-group, within-group, and interaction effects. An alpha level of .05 was used for all statistical analyses. Statistical analyses were conducted with PASW Statistics 17 for Windows (SPSS Inc, Chicago, Illinois).

An a priori power analysis was conducted to estimate the number of participants needed to obtain a statistical power of .80 at an alpha level of .05. In a meta-analysis study of the effect of resistance training on muscle strength, a standardized effect size of 2.0 was calculated for an improvement in muscle strength. In a meta-analysis study of the effect of aerobic training on exercise capacity in people with type 2 diabetes, a standardized effect size of 0.5 was calculated. The a priori power analysis estimated that a total sample size of 18 participants would detect a standardized effect size of 0.5 for between-group differences in improvements in muscle strength and exercise capacity at a statistical power of at least .80 and an alpha level of .05.

Results
The Figure is a flow chart illustrating the randomized clinical trial. A total of 28 potential participants with type 2 diabetes were assessed for eligibility; 7 of the 28 were excluded because they did not meet the inclusion criteria. Ten participants were randomly allocated to the MOD group, and 11 participants were randomly allocated to the HIGH group. After allocation, 1 participant in the HIGH group withdrew from the investigation for reasons unrelated to the study (lack of time because of work schedule). Data for glucose levels immediately after exercise and 1 hour after exercise could not be collected from 1 participant in the MOD group because this participant consumed glucose during the first exercise training session.

Baseline characteristics and muscle strength, exercise capacity, and physical function outcome scores for the MOD group and the HIGH group are shown in Tables 2 and 3. The analysis of variance indicated no statistically significant difference (P>.05) in baseline characteristics or initial outcome scores between the groups. The general linear model indicated no statistically significant difference in improvements in exercise capacity (P=.07), muscle strength (P=.33), or physical function (P=.63) between the groups over time. Statistically significant improvements in all of these outcomes were found for both groups (P<.001).

Mean glucose levels immediately before exercise, immediately after exercise, and 1 hour after exercise for the MOD group were 204.5 mg/dL (SD=92.3), 181.1 mg/dL (SD=84.2), and 172.0 mg/dL (SD=81.3), respectively; those for the HIGH group were 140.0 mg/dL.
(SD=34.4), 109.8 mg/dL (SD=17.9), and 118.5 mg/dL (SD=33.2), respectively. The MOD group participated in a mean of 33.6 exercise training days (SD=2.7) and spent a mean total exercise time of 1,552.0 minutes (SD=147.5) during the 3-month exercise program. The HIGH group participated in a mean of 36.7 exercise training days (SD=6.7) and spent a mean total exercise time of 1,429.0 minutes (SD=322.2) during the 3-month exercise program. The analysis of variance indicated no significant difference in adherence in terms of exercise training days ($P=.22$) or exercise time ($P=.28$) between the groups. One participant in the MOD group reported symptoms of mild hypoglycemia during the first session of exercise training; these were resolved with the consumption of water and glucose tablets, and the participant was able to complete the exercise training session and the remainder of the study without incident. This participant’s symptoms were considered a minor, expected adverse event. No other adverse events were reported over the course of this investigation.

**Discussion**

This investigation is the first randomized clinical trial of the effects of exercise training intensity on physical fitness and physical function in people with type 2 diabetes. The results of this investigation indicated statistically significant improvements in all outcomes in both groups. However, gains in exercise capacity, mus-

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**Figure.**

Randomized clinical trial flow chart. MOD=moderate-intensity exercise training, HIGH=high-intensity exercise training.
cle strength, and physical function were not statistically significantly different between the groups. Participants in both the MOD group and the HIGH group demonstrated significant and similar gains in muscle strength, exercise capacity, and physical function during the 3-month trial.

The AHA, ADA, and ACSM recommend combined resistance training and aerobic training for people with type 2 diabetes and provide evidence-based guidelines for prescribing exercise training in terms of intensity, volume, frequency, duration, and rate of progression. In the present study, the variable of intensity was different between the groups, whereas the variables of volume, frequency, duration, and rate of progression were identical. On the basis of the findings of the present study, people who have type 2 diabetes and participate in exercise training at either a moderate intensity or a high intensity, as defined by the AHA, may experience similar gains in muscle strength, exercise capacity, and physical function when the other dosing variables are the same.

The finding of no significant difference in improvements in muscle strength between the groups may be explained by the magnitude of the difference in exercise training intensity between the groups. The HIGH group experienced a 25% higher intensity of resistance training than the MOD group. However, this magnitude of the difference in resistance training intensity between the groups was not seemingly large enough to result in a significant difference in muscle strength gains between the groups. Such an explanation can be supported by the results of resistance training studies in people without type 2 diabetes. For example, in older adults, a greater gain in muscle strength from resistance training has been observed as the size of the difference in resistance training intensity increases. In a meta-analysis, Steib et al calculated muscle strength effect sizes for studies in which high-intensity (defined as >75% of the 1-repetition maximum) resistance training and moderate-intensity (defined as 55%-75% of the 1-repetition maximum) resistance training were used for older adults. Pooled data indicated that the high intensity resulted in larger effect sizes than the moderate intensity (standardized mean difference = 0.62, 95% CI = 0.22, 1.03). Therefore, the magnitude of the difference in resistance training intensity between the groups may not have been adequate to result in a significant difference in increases in muscle strength between the groups.

Exercise capacity improved in a similar fashion for participants in both the MOD group and the HIGH

Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Moderate-Intensity Exercise Training Group</th>
<th>High-Intensity Exercise Training Group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex (men/women)</strong></td>
<td>5/5</td>
<td>7/4</td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
<td>52.2 (12.6)</td>
<td>54.4 (5.6)</td>
</tr>
<tr>
<td><strong>Body mass, kg</strong></td>
<td>111.7 (23.5)</td>
<td>106.7 (15.7)</td>
</tr>
<tr>
<td><strong>Height, cm</strong></td>
<td>173.0 (9.0)</td>
<td>175.5 (10.5)</td>
</tr>
<tr>
<td><strong>Medication use (no. of participants)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metformin</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Sulfonylurea</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Thiazolidinedione</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Insulin</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

* Data are reported as mean (SD) for continuous variables and counts for dichotomous variables.

Table 3.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moderate-Intensity Exercise Training Group</td>
</tr>
<tr>
<td><strong>Physical function</strong></td>
<td>4.3 (0.7)</td>
</tr>
<tr>
<td><strong>Muscle strength, N·m</strong></td>
<td>132.8 (47.1)</td>
</tr>
<tr>
<td><strong>Exercise capacity, min</strong></td>
<td>9.0 (3.7)</td>
</tr>
</tbody>
</table>

* Data are reported as mean (SD).

* Data are reported as mean (SD) on the basis of the general linear model results.

* Data are reported as the estimated marginal mean difference (95% confidence interval) on the basis of the general linear model results.
group. Hansen et al.²³ investigated the effects of 2 different aerobic training intensities on exercise capacity in people with type 2 diabetes and found that at 2 months, participants in the higher-intensity group (training at 75% of peak oxygen uptake) demonstrated statistically significant greater gains in exercise capacity than participants in the moderate-intensity group (training at 50% of peak oxygen uptake). However, Hansen et al.²³ reported that at 6 months, there was no statistically significant difference in improvements in exercise capacity between the groups. Therefore, the findings of Hansen et al.²³ suggested that in the short term, exercise training at a higher intensity was more beneficial than that at a moderate intensity, whereas in the long term, exercise training at a moderate intensity was as effective as that at a high intensity. The findings of the present study differ from those of the meta-analysis study by Boule et al.,²⁰ who concluded that exercise training at a higher intensity could have additional benefits for improving exercise capacity in people with type 2 diabetes. Also, as with resistance training, the magnitude of the difference in aerobic training intensities may determine the degree of improvements in exercise capacity.

Exercise capacity was measured by use of a graded exercise test with 2 endpoints. The graded exercise test was continued until a participant either reached 85% of the age-predicted heart rate maximum or voluntarily stopped the test because of exhaustion, whichever endpoint occurred first. One participant in each group voluntarily ended the test at baseline yet reached 85% of the age-predicted heart rate maximum after the intervention. The procedures for the graded exercise test (including these endpoints) were shown to be reliable in previous research and are considered to be standard for the graded exercise test. However, improvements in exercise tolerance (which is a component of exercise capacity) may have contributed to gains in exercise capacity in the aforementioned 2 participants. Nevertheless, exercise capacity was validly measured in the present study, and improvements in both groups exceeded the minimal detectable change of 0.86 minute.³³ Furthermore, chi-square analysis indicated no significant difference ($P>0.05$) between the groups with regard to who voluntarily ended the test at baseline yet reached 85% of the age-predicted heart rate maximum after the intervention, and there was no significant difference in exercise capacity gains between the groups.

There was no significant difference in improvements in physical function between the MOD group and the HIGH group. A possible reason for the similar gains in physical function between the groups is the correlation between physical fitness and physical function in people with type 2 diabetes. People with type 2 diabetes are more likely to experience a greater loss of muscle strength, and decreased muscle strength is associated with a decreased level of physical function.⁴⁷ Also, people with type 2 diabetes typically have diminished exercise capacity, and decreased exercise capacity is related to physical disability.⁵,⁴¹ The similar improvements in muscle strength and exercise capacity found between the groups in the present study could explain the similar gains in physical function.

Muscle strength, exercise capacity, and physical function are meaningful outcomes for people with type 2 diabetes. The findings of the present study indicate that people with type 2 diabetes may achieve similar gains in muscle strength, exercise capacity, and physical function with either moderate-intensity exercise training or high-intensity exercise training. If the goal is to improve muscle strength, exercise capacity, or physical function, then clinicians can choose either intensity and may observe similar outcomes. The preference for implementing either a moderate-intensity exercise training program or a high-intensity exercise training program for people with type 2 diabetes is important, especially given the inverse relationship between exercise training intensity and the adherence of people to the program.⁴²

The statistical power, effect sizes, and sample size of the present study should be considered before drawing the absolute conclusion that moderate-intensity exercise training and high-intensity exercise training are equally effective in people with type 2 diabetes. Although an a priori power analysis was performed and the required sample size was achieved, the between-group effect sizes (partial $\eta^2$) of 0.04 (95% CI=0.00, 0.29), 0.15 (95% CI=0.00, 0.42), and 0.01 (95% CI=0.00, 0.21) for muscle strength, exercise capacity, and physical function, respectively, were relatively small. A larger sample size may be needed to detect such small between-group effects.

One potential limitation of this randomized clinical trial was that energy expenditure and total work were not controlled between the groups. Given the relatively small between-group effect sizes and the findings of no significant differences in outcomes between the groups, the lack of control of energy expenditure and total work likely did not affect the results. The participants in the present study were unaware of group assignment, but the investigators who collected the outcomes data were not, and encouragement of participants during testing may have
had an influence. A larger sample size would have improved generalizability. Although validated as a measure of physical function, the Patient-Specific Functional Scale is a subjective assessment of physical function and may not be as precise as more objective tests, such as a battery of physical function tests (eg, validated walking, stair climbing, chair rising assessments). The glucose data should be interpreted with caution because of method flaws, such as the assessment of glucose regardless of the time since the last meal, medication use, or insulin use. For transparency of reporting outcomes, we reported means and standard deviations of the data. Further statistical analyses of the glucose data were not performed to avoid being misleading. Future research addressing the limitations of the present study is warranted. Also, additional trials of exercise training intensities with greater magnitudes of difference are needed to identify the optimal exercise training intensity for people with type 2 diabetes.

In conclusion, clinicians may observe similar improvements in muscle strength, exercise capacity, and physical function in people with type 2 diabetes when either high-intensity exercise training or moderate-intensity exercise training is prescribed in accordance with current evidence-based guidelines. Physical therapists can make an evidence-based choice of either moderate-intensity exercise training or high-intensity exercise training for people with type 2 diabetes while also considering other variables, such as a patient’s overall health status.

Dr Taylor, Dr Fletcher, and Dr Cade provided concept/idea/research design. All authors provided writing. Dr Taylor, Dr Fletcher, and Dr Mathis provided data collection. Dr Taylor and Dr Mathis provided data analysis, project management, and participants. Dr Cade provided consultation (including review of manuscript before submission). This study was approved by the University of Central Arkansas Institutional Review Board. This randomized clinical trial is registered at ClinicalTrials.gov (registration number: NCT01417845).


References
Moderate- Versus High-Intensity Exercise Training in People With Type 2 Diabetes


