Effects of Combined Aerobic and Resistance Training on Muscle Strength in Middle-Aged Type 2 Diabetics

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ABSTRACT

Background: Type 2 diabetes (T2D) is a prevalent metabolic disorder associated with various complications, including muscle weakness, which can affect quality of life. Combined aerobic and resistance exercises have shown potential in improving physical strength and function in T2D patients, but the specific effects on muscle strength in elderly diabetic patients remain underexplored.

Objective: This study aimed to investigate the effects of combined aerobic and resistance exercise on muscle strength in geriatric patients (aged 40–60 years) with Type 2 diabetes.

Methods: A quasi-experimental study was conducted with 30 participants diagnosed with Type 2 diabetes. Participants were enrolled through convenient sampling and completed a 12-week exercise program consisting of aerobic exercises (walking, running, cycling) and resistance exercises (step-ups, bodyweight exercises, and resistance bands). The muscle strength of key muscle groups, including knee extensors, knee flexors, ankle dorsiflexors, shoulder abductors, elbow flexors, and hip flexors, was measured before and after the intervention using both dynamometry (force in Newtons) and Manual Muscle Testing (MMT) (0–5 scale). Paired t-tests were used to compare pre- and post-test results, and effect sizes (Cohen's *d*) were calculated for dynamometry data.

Results: Significant improvements were observed in all muscle groups post-intervention. The knee extensors showed the greatest improvement (21.5%, $p < 0.001$), followed by knee flexors (17.0%, $p < 0.001$), and ankle dorsiflexors (15.6%, $p < 0.001$). The effect sizes for dynamometry measurements ranged from moderate to large (Cohen's d = 0.61–1.52). Additionally, MMT scores showed a significant increase in muscle strength across the assessed muscle groups ($p < 0.001$).

Conclusion: The results suggest that a combined aerobic and resistance exercise program can significantly enhance muscle strength in geriatric patients with Type 2 diabetes. These findings emphasize the importance of incorporating both aerobic and resistance exercises in managing muscle weakness in T2D, potentially improving functional capacity and reducing the risk of diabetic complications in elderly patients.

Keywords: Resistance training, Type 2 diabetes mellitus, Combined exercise, Geriatric population

INTRODUCTION

Type 2 diabetes mellitus (T2DM) in middle-aged and older adults is often accompanied by skeletal muscle weakness and accelerated sarcopenia【2】. Insulin resistance and nonenzymatic glycation can impair muscle contractility in diabetes, leading to reduced muscle mass and strength compared to non-diabetic peers【2】. For example, Nomura et al. note that elderly diabetic patients have significantly lower lower-limb muscle mass and strength than age-matched controls. This decline in muscle function contributes to reduced functional capacity and higher fall risk in diabetes. Importantly, exercise training can counteract these deficits. Jeong and Sohn report that resistance exercise "improves muscle strength and endurance" and that combining resistance with aerobic exercise "improves insulin resistance and controls blood glucose levels" in diabetic patients. Accordingly, diabetes management guidelines recommend both aerobic and resistance exercise: for instance, the ADA position statement advocates ≥150 min/week of moderate aerobic activity plus regular resistance training for older adults with T2DM. Randomized trials have confirmed these benefits; one study found that a 12-week combined aerobic–resistance program raised knee flexor and extensor strength by 15–30% and reduced muscle fatigue in T2DM patients. Early-onset Type 2 diabetes is associated with more aggressive disease progression and greater risk of complications, including cardiovascular disease and neuropathy. Individuals diagnosed at a younger age tend to experience a longer duration of hyperglycemia, increasing the risk for long-term microvascular and macrovascular damage (Wilmot & Idris, 2014). Specifically, combined exercise training positively affects lipid profiles, insulin sensitivity, and body composition. It has also been shown to improve physical fitness and muscular performance, which are crucial for the overall health and autonomy of individuals living with diabetes (Tambalis et al., 2009).

In summary, combined exercise appears fundamental for improving muscle function in diabetes. However, few studies have specifically measured changes in muscle strength using clinical tools in 40–60-year-old diabetic patients. This study therefore evaluated the impact of a 12-week combined aerobic-plus-resistance training program on muscle strength in middle-aged T2DM patients. We hypothesized that the intervention would significantly increase strength in key muscle groups.

METHODOLOGY

- Study Design:
  - Quasi-experimental study design to evaluate the effects of combined aerobic and resistance exercise on muscle strength in Type 2 diabetes patients.
- Sampling:
  - Sampling Method: Convenient sampling technique was used to select participants.
  - Sample Size: A total of 30 geriatric elderly participants, aged between 40 to 60 years, diagnosed with Type 2 diabetes.
- Inclusion Criteria:
  - Both male and female participants.
  - Age between 40 and 60 years.
  - Diagnosed with Type 2 diabetes.
- Exclusion Criteria:
  - Participants with foot trauma, fever, bone dislocation, rheumatoid arthritis, posterior tendonitis, congenital defects, or central nervous system disorders.
  - Participants with any additional musculoskeletal or neurological impairments that could interfere with exercise participation.
- Intervention:
  - Exercise Program:
    - Aerobic exercises: Walking, running, cycling, and step-up/step-down exercises (performed on a chair or stairs).

- Resistance exercises: Focused on strengthening the lower and upper body using bodyweight exercises and resistance bands.

- Frequency: The intervention lasted for 12 weeks, with exercise sessions conducted 3 times per week.

OUTCOME MEASURE

- Manual Muscle Testing (MMT): Used to evaluate the muscle strength of the lower and upper limbs.
- Dynamometry: A handheld dynamometer was used to measure the force output of specific muscle groups (knee extensors, knee flexors, ankle dorsiflexors, etc.).

STATISTICAL PROCEDURE

- Descriptive statistics: Mean and standard deviation were calculated for each muscle strength measurement.
- Paired t-test: To determine significant differences between pre-test and post-test muscle strength values within the same group.
- Effect size (Cohen's *d*): Calculated for the dynamometry data to assess the magnitude of the intervention effect.

RESULT

The intervention consisting of combined aerobic and resistance exercises significantly improved muscle strength in participants with Type 2 diabetes. Pre-test and post-test muscle strength measurements were compared using paired t-tests, and significant improvements were observed across all measured muscle groups.

- Knee Extensors: The strength of the knee extensors, measured using a dynamometer, improved by 31.9 N (21.5%), from 148.2 N to 180.1 N, with a large effect size of 1.52.
- Knee Flexors: The knee flexors showed an improvement of 22.1 N (17.0%), from 130.3 N to 152.4 N, with a large effect size of 1.18.
- Ankle Dorsiflexors: Ankle dorsiflexor strength increased by 7.0 N (15.6%), from 45.0 N to 52.0 N, with a moderate effect size of 0.94.
- Shoulder Abductors: Shoulder abductors saw a moderate improvement of 7.4 N (9.5%), from 77.9 N to 85.3 N, with a small to moderate effect size of 0.68.
- Elbow Flexors: Elbow flexor strength improved by 6.5 N (9.1%), from 71.7 N to 78.2 N, with a small effect size of 0.61.
- Manual Muscle Testing (MMT): In the manual muscle test (MMT), a significant improvement in muscle strength was noted for the knee extensors, ankle dorsiflexors, and hip flexors, with the average MMT score increasing by 0.7–0.8 points in each group.

DISCUSSION

This study demonstrates that a 12-week program combining aerobic and resistance exercise significantly increases muscle strength in middle-aged T2DM patients. Increases of 15–22% in leg strength and smaller (~8–9%) but significant gains in arm strength were observed. These findings extend prior reports and support current exercise guidelines. For instance, Tomas-Carus et al. showed 15–30% improvements in knee extensor and flexor strength after 12 weeks of combined training in T2DM patients, consistent with our 21% knee extensor gain. Likewise, Lee et al.'s meta-analysis in older diabetics found that resistance training markedly improved muscle strength (standardized mean difference >0.8). Our data are also in line with the ADA/ACSM recommendation that T2DM patients undertake both aerobic and resistance exercises to optimize strength and glycemic outcomes.

Mechanistically, the strength improvements likely reflect muscle hypertrophy and neural adaptations. Chronic hyperglycemia in diabetes impairs muscle protein synthesis and neuromuscular junction function. Combined aerobic–resistance training enhances muscle glucose uptake, insulin signaling, and capillarization. Resistance exercise in particular increases muscle fiber size and neuromuscular firing, explaining the large strength gains observed. Our use of Manual Muscle Testing (MMT) plus hand-held dynamometry provided both functional and quantitative assessments of strength. Bohannon notes that MMT has been used for over a century to gauge muscle output by grading observed effort and resistance, which complements dynamometer measurements.

The improvements in muscle strength have important clinical implications. Stronger lower limbs enhance gait, balance, and ability to perform daily activities. Strength training may also mitigate diabetic peripheral neuropathy (DPN) effects: Orlando et al. review that DPN causes profound loss of muscle mass and strength, especially in the legs, but that exercise training can partially reverse these deficits. In their narrative review, combined training even "restores small sensory nerve damage" and improves overall muscle function in neuropathic patients. Thus, by improving strength and possibly nerve health, combined exercise could reduce fall risk and functional decline in older diabetics. Indeed, progressive resistance has been shown to alleviate neuropathic pain and improve nerve conduction when used along with aerobic activity.

Our results also suggest that middle-aged diabetic adults can achieve strength gains comparable to those reported in elderly cohorts This underscores the importance of early intervention to prevent sarcopenia. The magnitude of strength increase in our study (Cohen's d>1.0 for knee muscles) is clinically meaningful. Given that diabetes is an independent risk factor for reduced muscle strength and functional decline, these exercise-induced gains may translate into better metabolic control and quality of life.

Notably, no adverse events occurred, indicating the regimen was well tolerated. Supervision and individualized progression likely contributed to safety. This is consistent with recommendations for older patients: ADA guidelines explicitly advise resistance and balance exercises 2–3 times per week for older adults with diabetes to preserve strength and prevent falls. Our findings support incorporating such combined training into routine care for middle-aged and elderly diabetic patients.

Limitations include the lack of a non-exercise control group and a relatively small sample size. However, the within-subject design and highly significant paired t-test results (p<0.005) strengthen the findings. Future studies could use randomized controlled designs and longer follow-up to assess lasting benefits and impacts on neuropathy. Objective dynamometry and MMT proved useful here, though MMT's ordinal scale can limit sensitivity at high strength levels

In conclusion, a structured 12-week program of combined aerobic and resistance exercise markedly enhances muscle strength in 40–60-year-old T2DM patients. These gains, consistent with existing literature, highlight the critical role of multicomponent exercise in preserving muscle function in diabetes. Clinicians and therapists should therefore promote regular strength training alongside aerobic exercise in the geriatric diabetic population to improve mobility, metabolic control, and potentially slow neuropathic progression.

Table 1. Changes in Muscle Strength Before and After 12-Week Combined Exercise Intervention (n = 30)

Muscle Group	Measurement Tool	Pre-Test Mean ± SD	Post-Test Mean ± SD	Mean Difference	% Improvement	p-value	Effect Size (Cohen's d)
Knee Extensors	Dynamometer (N)	148.2 ± 21.6	180.1 ± 24.8	+31.9	+21.5%	< 0.001	1.52
Knee Flexors	Dynamometer (N)	130.3 ± 19.9	152.4 ± 23.5	+22.1	+17.0%	< 0.001	1.18
Ankle Dorsiflexors	Dynamometer (N)	45.0 ± 8.1	52.0 ± 9.3	+7.0	+15.6%	< 0.001	0.94
Shoulder Abductors	Dynamometer (N)	77.9 ± 11.2	85.3 ± 11.7	+7.4	+9.5%	0.001	0.68
Elbow Flexors	Dynamometer (N)	71.7 ± 10.4	78.2 ± 10.9	+6.5	+9.1%	0.002	0.61
Hip Flexors	Manual Muscle Test (0–5)	3.4 ± 0.5	4.1 ± 0.5	+0.7	—	< 0.001	—
Knee Extensors	Manual Muscle Test (0–5)	3.2 ± 0.5	4.0 ± 0.4	+0.8	—	< 0.001	—
Ankle Dorsiflexors	Manual Muscle Test (0–5)	3.0 ± 0.6	3.7 ± 0.5	+0.7	—	< 0.001	—

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