Research Article / Araştırma Makalesi
doi: 10.18678/dtfd.1109209

Duzce Med J, 2022;24(3):235-240
Düzce Tıp Fak Derg, 2022;24(3):235-240

The Effect of Combination of Aerobic and Strengthening Exercise on Muscle Strength, Balance, and Sleep Quality in Individuals with Type 2 Diabetes

Tip 2 Diyabet Olan Bireylerde Aerobik ve Kuvvetlendirme Egzersiz Kombinasyonunun Kas Gücü, Denge ve Uyku Kalitesi Üzerine Etkisi

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Received / Geliş Tarihi : 26.04.2022
Accepted / Kabul Tarihi : 29.08.2022
Available Online / Çevrimiçi Yayın Tarihi : 23.09.2022

ABSTRACT

Aim: The aim of this study was to determine the effects of aerobic and strengthening exercise combination on glycosylated hemoglobin (HbA1c), muscle strength, balance, and sleep quality in individuals diagnosed with type 2 diabetes mellitus (DM).

Material and Methods: Fifty individuals aged between 30 and 65 years and diagnosed with type 2 DM were included in this study. Anthropometric measurements, HbA1c, quadriceps and hamstring muscle strength, balance, and sleep quality of the included individuals were evaluated. Aerobic and strengthening exercises were applied to the participants 3 days a week for 12 weeks. All evaluation measurements were repeated at the end of 12 weeks.

Results: Of the 50 individuals included in this study and diagnosed with type 2 DM, 64% (n=32) were male and 36% (n=18) were female. The mean age of the participants was 50.12±10.81 years, the mean body mass index was 29.97±3.12 kg/m^2, the waist/hip ratio was 0.91±0.08, and the mean HbA1c was 9.19±2.39. When the pre and post-treatment HbA1c, muscle strength, balance, and sleep quality measurements of all participants were compared, there were statistically significant differences ($p<0.001$).

Conclusion: It was determined that the combination of long-term aerobic and strengthening exercise decreased the HbA1c value and also significantly improved muscle strength, balance, and sleep quality in individuals with type 2 DM. A structured exercise program that includes strengthening and aerobic exercises would be beneficial in developing the most effective and appropriate exercise prescriptions in terms of exercise efficiency and sustainability for individuals with type 2 DM.

Keywords: Aerobic exercise; balance; muscle strength; strengthening exercises; type 2 diabetes.

ÖZ

Amaç: Bu çalışmanın amacı, tip 2 diabetes mellitus (DM) tanısı olan bireylerde aerobik ve kuvvetlendirme egzersiz kombinasyonunun glikozile hemoglobin (HbA1c), kas kuvveti, denge ve uyku kalitesi üzerine etkilerini belirlemektir.

Gereç ve Yöntemler: Bu çalışmaya 30 ve 65 yaş arası ve tip 2 DM tanısı olan 50 birey dahil edildi. Dahil edilen bireylerin antropometrik ölçümleri, HbA1c, quadriseps ve hamstring kas gücü, denge ve uyku kalitesi değerlendirildi. Katılımcılara 12 hafta boyunca haftada 3 gün aerobik ve kuvvetlendirme egzersizleri uygulandı. Tüm değerlendirme ölçümleri 12 haftanın sonunda tekrar edildi.

Bulgular: Bu çalışmaya dahil edilen ve tip 2 DM tanısı olan 50 bireyin %64'ü (n=32) erkek ve %36'sı (n=18) kadın idi. Katılımcıların yaş ortalaması 50,12±10,81 yıl, ortalama beden kitle indeksi 29,97±3,12 kg/m^2, bel/kalça oranı 0,91±0,08 ve ortalama HbA1c değeri 9,19±2,39 idi. Tüm katılımcıların tedavi öncesi ve tedavi sonrasındaki HbA1c, kas gücü, denge ve uyku kalitesi ölçümleri karşılaştırıldığında istatistiksel olarak anlamlı farklar vardı ($p<0,001$).

Sonuç: Tip 2 DM olan bireylerde uzun süreli aerobik ve kuvvetlendirme egzersizi kombinasyonunun HbA1c değerini azalttığı ve ayrıca kas gücü, denge ve uyku kalitesini de önemli ölçüde iyileştirdiği belirlendi. Kuvvetlendirme ve aerobik egzersizleri içeren yapılandırılmış bir egzersiz programı, tip 2 diyabet olan bireyler için egzersiz etkinliği ve sürdürülebilirliği açısından en etkili ve uygun egzersiz reçetelerinin geliştirilmesinde faydalı olacaktır.

Anahtar kelimeler: Aerobik egzersiz; denge; kas gücü; kuvvetlendirme egzersizleri; tip 2 diyabet.

INTRODUCTION

Type 2 diabetes mellitus (DM) is the most common metabolic disease characterized by insulin resistance and increased glucose production in the adult population. Type 2 DM, also known as 'non-insulin-dependent diabetes', accounts for more than 90% of all diabetes cases. While type 2 diabetes affects 5-10% of the population in developed countries, it affects 10-25% of the population in developing countries. Although type 2 DM is known as a middle and advanced-age disease, it has also been seen at earlier ages in recent years. In people who are genetically predisposed to type 2 DM, it is observed that insulin resistance increases over time, as obesity increases and physical activity decreases as a result of negative lifestyle changes (1,2).

Muscle atrophy occurs as a result of the loss of strength in the skeletal muscles of individuals with diabetes depending on the duration of diabetes. In addition, deterioration in blood values (especially fasting blood sugar, glycosylated hemoglobin, and cholesterol levels), postprandial hyperglycemia, systolic and diastolic blood pressure problems, deterioration of functionality, loss of balance, and decrease in quality of life occur (3,4).

Physical activity and regular exercise programs, as well as pharmaceutical treatment and diet approaches, are demonstrated to be the most effective in the treatment of type 2 diabetes research. It is known that exercise can prevent or delay type 2 diabetes symptoms and complications (5). Studies have shown that exercise training has beneficial effects on the glycemic profile, such as decreased glycosylated hemoglobin (HbA1c) level, increased maximum oxygen consumption (VO_2 max), and improved insulin sensitivity in diabetic patients (6,7). Exercise in individuals with type 2 diabetes improves glycemic control, lowers blood pressure, reduces abdominal fat mass, reduces cardiovascular morbidity and mortality, and positively affects balance and quality of life. In addition, exercise affects falls, injury, and balance factors by improving insulin sensitivity and function (4,8). Aerobic and strengthening exercises assist individuals with type 2 diabetes control their glucose levels. Aerobic exercises facilitate the uptake and distribution of oxygen to the body. Exercise reduces HbA1c level, lipid level, body fat percentage, blood pressure, insulin resistance, and inflammation parameters. On the other hand, strengthening exercises provide glycemic control and normalize fat mass and blood pressure in individuals with type 2 DM. Combining strengthening and aerobic activities has a two-fold greater impact on metabolic parameters than performing these exercises separately (9). Although combined exercises have been shown to improve HbA1c, fasting and postprandial glucose levels, and insulin sensitivity, studies on the effects on balance, muscle strength, and sleep quality are limited. The impact of the structured versions of both exercises on patients differs based on comorbidities, patient preference, equipment, and clinical availability (10,11).

The effectiveness of different exercise programs has been studied, but studies examining the effects of structured aerobic and strengthening exercises on individuals with type 2 DM seem to be insufficient. Also, it is unclear whether exercise programs improve muscular strength, balance, and sleep quality in people with type 2 DM. We anticipate that combining exercises will be more effective for reducing HbA1c and improving mobility function. The study aimed to examine the effects of structured exercise programs on muscle strength, balance, and sleep quality in individuals with type 2 diabetes.

MATERIAL AND METHODS

Study Design and Participants

The study was conducted with 50 individuals with type 2 diabetes who were followed up in the Department of Endocrine and Metabolism Diseases of Istanbul Medipol University Hospital in Istanbul. All participants were recruited between December 2021 and March 2022. This study was approved by the Non-interventional Clinical Researches Ethics Committee at Istanbul Medipol University (dated: 09.12.2021 and numbered: 1262). All participants signed written information and provided an informed consent form, and the study was conducted by the principles of the Declaration of Helsinki.

The participants who were 30-65 years of age, had body mass index (BMI) of 25-30 kg/m^2, HbA1c ≥6.5%, fasting blood glucose >126 mg/dl, and type 2 DM between 5-10 years were included in the study. The exclusion criteria were defined as having type 1 DM or having any neurologic, cardiac, or orthopedic diseases that would prevent exercise participation.

The sample size was determined using the G* power sample size calculator (G* Power, v.3.1.9.7). The required sample size was calculated as 47 using the "difference between two dependent means (matched pairs)" model with 95% power (δ= 3.35, effect size=0.5, t=1.68) considering the HbA1c value (10).

Intervention

The supervised structured moderate-vigorous intensity aerobic and resistance training was applied to the participants 3 days a week for 12 weeks. Simple to difficult repetitive movements and walking exercises without equipment were used in aerobic exercises. The progression of the exercises was determined by the Borg rating of perceived exertion (RPE) scale. The amount of fatigue felt on the Borg RPE scale increased from 11-12 to 13-14 when moderate-intensity aerobic exercises were performed. Strengthening exercises consisted of exercises for shoulder girdle muscles, flexor and extensor muscles of knee and hip, abdominal muscles, and trunk extensor muscles. Theraband resistance was increased every 12 sessions for the progression of the strengthening exercises in the 36-session exercise program, which has been separated into three parts. Exercises were performed using a red-colored theraband, 8 repetitions, and 1 set in the first 12 sessions. Exercises were repeated with the green-colored theraband in the second 12 sessions, increasing the number of repetitions from 8 to 10, and the number of sets from 1 to 3. The exercises were performed with the blue-colored theraband in the last 12 sessions, with the number of repetitions and sets rising according to the patient's condition.

A dietitian created a diet plan for all of the study participants to maintain a consistent calorie intake. For all participants, a diabetic diet consisting of 1800 calories, 46 percent carbohydrates, 18 percent protein, and 36 percent fat was standardized. The participant's compliance with the diet program was evaluated.

Outcome Measurements

Demographic information and anthropometric measurements such as age, weight, height, waist circumference, waist/hip ratio, BMI, and disease duration of all individuals participating in the study were obtained. During the evaluation process of the participants, HbA1c measurements, muscle strength measurements, balance, and sleep quality evaluations were performed.

Body Composition Assessment

Basic anthropometric measurements included weight, height, waist circumference (level of umbilicus), and hip circumference (largest protrusion of the buttocks), measured to the nearest 0.1 cm. BMI was calculated as kg/m^2.

HbA1c Measurement

HbA1c blood test evaluation of all participants was obtained from the Istanbul Medipol University laboratory.

Muscle Strength Evaluations

Myometer was used to evaluate hamstring and quadriceps muscle strength. Myometer is a device that allows for measuring muscle strength objectively. During muscle strength measurement, the patient is first positioned. Then the myometer is placed on the distal side of the area to be measured. The force applied patient is asked to maintain his position. At the point where the patient cannot continue the movement, the force application is stopped and the maximum force recorded by the device is recorded. Each measurement was repeated 3 times, and the average of the test was recorded as kilograms (12).

Single Leg Stance Test

A single-leg stance test was used for balance assessment. For this test, the participants were asked to stand for 30 seconds without falling, with the non-evaluated side knee in 90° flexion. The stopwatch was started as soon as the foot was lifted off the ground. Each falling move was recorded as a score to keep the individual's balance. The test was repeated 3 times for the right and left leg and the average was taken (13). The validity and reliability of the single leg balance test were done by Sarac et al. (14).

Pittsburgh Sleep Quality Index

It is a scale that provides a quantitative measurement of sleep quality to define good and bad sleep developed by Buysse et al. (15) in 1989. The validity and reliability of the Pittsburgh sleep quality index (PSQI) were done by Agargun et al. (16) in 1996. It contains a total of 24 questions. 19 of these questions are self-evaluation questions, and 5 of them are answered by the spouse or roommate of the individual. The 18 items scored are grouped into 7 components. These seven component scores give the overall score. The total score is between 0-21. A high score indicates low sleep quality (15).

Statistical Analysis

IBM SPSS v.25.0 for Windows was used for statistical analysis. The normal distribution of the variables was tested by the Kolmogorov-Smirnov test. The comparison of the participants' pre and post-treatment evaluations was done with paired samples t-test in dependent samples. The significance value was accepted as $p<0.05$.

RESULTS

The study was completed with 50 participants with type 2 DM. The demographic and clinical characteristics of the participants were shown in Table 1. 32 (%64) of the participants were female and 18 (%36) were male. The mean age of the participants was 50.12±10.81 years, the mean BMI was 29.97±3.12 kg/m^2, and the waist/hip ratio was 0.91±0.08. In addition, 18 (%36) of the participants are type 2 DM between 0-5 years, 12 (%24) of them are type 2 DM between 5-10 years, and 20 (%40) of them are type 2 DM for more than 10 years. 22 (%24) of the participants use drugs, 12 (24%) of them use drugs and insulin, and 16 (32%) of them use insulin. When the participants' pre and post-treatment HbA1c, muscle strength, balance, and sleep quality measurement results were compared, there was a statistically significant difference in all parameters ($p<0.001$, Table 2). HbA1c values statistically significantly decreased after treatment. Muscle strength results of hamstring, quadriceps, and deltoid muscles significantly increased after treatment. Also, balance scores statistically significantly increased.

DISCUSSION

It was aimed to examine the effects of 12 weeks of aerobic and strengthening exercises on HbA1c value, muscle strength, balance, and sleep quality. It was observed that the exercises provided significant improvement on all variables.

Table 1. Demographic and clinical characteristics of the participants with type 2 DM

Age (years), mean±SD (min-max)	50.12±10.81 (30-65)
Gender, n (%)	
Female	32 (64)
Male	18 (36)
Height (cm), mean±SD (min-max)	164.60±9.74 (148-185)
Weight (kg), mean±SD (min-max)	82.28±11.78 (60-105)
WC (cm), mean±SD (min-max)	96.84±14.75 (70-133)
HC (cm), mean±SD (min-max)	106.04±14.42 (90-140)
BMI (kg/m^2), mean±SD (min-max)	29.97±3.12 (23.94-38.30)
WC/HC, mean±SD (min-max)	0.91±0.08 (0.67-1.07)
Age of DM, n (%)	
≤5 years	18 (36)
6-10 years	12 (24)
>10 years	20 (40)
Medical history, n (%)	
Oral drug	22 (44)
Drug+insulin	12 (24)
Insulin	16 (32)

DM: diabetes mellitus, SD: standard deviation, WC: waist circumference, HC: hip circumference BMI: body mass index

Table 2. Comparison of pre and post-treatment results

	Pre	Post	p
HbA1c (%)	9.19±2.39	7.26±1.30	**<0.001**
Right quadriceps MS	67.20±11.81	73.90±10.64	**<0.001**
Left quadriceps MS	64.85±12.59	70.29±11.41	**<0.001**
Right hamstring MS	60.97±12.25	65.52±12.50	**<0.001**
Left hamstring MS	54.82±12.59	60.36±12.56	**<0.001**
Right deltoid MS	57.45±10.22	62.16±9.58	**<0.001**
Left deltoid MS	55.81±11.23	61.91±10.06	**<0.001**
Right single LS	3.24±2.78	1.08±0.86	**<0.001**
Left single LS	3.92±2.64	1.32±0.94	**<0.001**
PSQI	10.16±3.28	6.48±2.67	**<0.001**

MS: muscle strength, LS: leg stance, PSQI: Pittsburgh sleep quality index

In the literature, it is stated that the incidence of type 2 DM is higher in females (1). When the genders of the individuals with type 2 DM who participated in this study were examined, 64% (n=32) were female. As in the results of epidemiological studies conducted in the field of type 2 DM in Turkey, the number of female participants in this study was higher than males (17). Routine doctor and nutritionist controls of all individuals were continued. We consider that these controls, which are repeated at regular intervals increase the effectiveness of the exercise program.

Hormonal and physical changes that occur in individuals with type 2 DM cause changes in body composition, increase the waist/hip ratio, and increase the risk of cardiovascular disease (18). In addition, changes in body composition in individuals with type 2 DM affect the musculoskeletal system, reducing the muscle strength and flexibility of individuals (19). As a result of the loss of strength in the skeletal muscles of individuals with diabetes, muscle atrophy accompanies the picture depending on the duration of diabetes. Changes occur in individuals such as deterioration in fasting blood sugar and glycosylated hemoglobin levels, postprandial hyperglycemia, systolic and diastolic blood pressure problems, and as a result, impairment of functionality, loss of balance, and decrease in sleep quality (3,4).

Exercise is one of the first treatment strategies recommended in the treatment of type 2 DM which has negative effects on many systems (7). In the American Diabetes Association (ADB), American Sports Medicine, and other current guidelines, it is reported that exercise is one of the most important strategies for the prevention and treatment of type 2 diabetes (1,20). Studies have shown that exercise training has beneficial effects on the glycemic profile, such as decreased HbA1c level, increased VO_2 max, and improved insulin sensitivity in diabetic patients. The risk of hypoglycemia increases in cases where the decrease in blood glucose levels cannot be controlled while performing exercise (21). For this reason, it is important to pay attention to all complications while creating an exercise program. In the present study, a structured exercise program specific to type 2 diabetes was created by considering cardiovascular risk factors and possible side effects. As a result, a decrease in the HbA1c value of participants was achieved.

Current national and international guidelines report that aerobic and resistance exercise training is effective in providing glycemic control for type 2 DM (22,23). In systematic reviews, positive effects of aerobic and resistance exercises have been proven on glycemic control, cardiovascular risk factors, and muscle strength in individuals with type 2 DM (23). Studies have shown that combining aerobic and strengthening exercises is more effective than aerobic or resistance exercises alone (24,25). Schwingshackl et al. (26), in a systematic review of 14 randomized controlled studies including 915 individuals with type 2 DM, reported that a combination of aerobic and strengthening exercise resulted in a greater reduction in HbA1c than aerobic or resistance training alone. In another meta-analysis, it was shown that an average of 0.6% reduction in HbA1c level can be achieved with combined aerobic and resistance exercise programs (27). In parallel with the literature, a structured exercise program consisting of aerobic and strengthening exercises was applied to individuals with type 2 DM for 12 weeks in the current study. It was observed that structured combined aerobic and strengthening exercises decreased the HbA1c value by 21%. We consider that the decrease in the HbA1c values of the individuals is related to the increase in blood glucose stores of the increased muscle mass with long-term exercise training under the supervision of a physiotherapist for 12 weeks.

Decreased muscle strength during type 2 DM also affects the physical activity level of individuals causing balance losses (28). In a study by Hameed et al. (29) on individuals with type 2 DM, it was stated that 12-week combined aerobic and progressive resistance exercises provided a statistically significant improvement in lower and upper extremity muscle strength. In individuals with type 2 DM, resistance exercise training increases muscle mass and strength, improves blood pressure, and thus positively affects metabolic control (30). In parallel with the literature, a significant improvement was found in bilateral quadriceps, hamstring, and deltoid muscle strength in this study. We consider that the significant increase in muscle strength is due to the fact that during 12 weeks of diabetes-specific structured aerobic and strengthening exercises increasing the resistance levels by changing the theraband color based on the tolerance of all individuals strengthens the mitochondrial structure in the muscle motor unit and causes changes in the volume of its fibers.

Balance problems also develop depending on the muscle strength and physical performance losses of individuals with type 2 DM (31). In a study, strengthening and sensorimotor exercises were given to individuals with type 2 DM for 4 weeks. At the end of 4 weeks, it was observed that there was a significant improvement in the test results of individuals standing on one leg (32). In the study of Lee et al. (33), a program consisting of stretching, balance, and aerobic exercises given 3 days a week for 6 weeks was applied to individuals with type 2 DM, and it was reported that there was an improvement in balance function as measured by the single-leg standing test and the timed sit and stand test (33). In the current study, the single-leg stance test was used to evaluate balance function, and a significant improvement was noted in balance function with structured aerobic and strengthening exercises. We believe that increasing muscle strength with a 12-week exercise program increases the improvement in balance function. We also propose that balance functions were improved by activating visual, vestibular, and proprioceptive stimuli together with aerobic and strengthening exercises. It is thought that exercises increase the elasticity of the muscles, muscle contraction speed, joint range of motion, the amount of oxygen coming to the muscle, and most importantly, the nerve conduction velocity contributes positively to proprioception, thus improving balance.

Studies have reported that disruptions in the glucose mechanism of individuals with diabetes impair sleep quality by making it difficult to fall asleep (34,35). It has been reported that individuals with type 2 DM have lower sleep and quality of life compared to individuals without diabetes (36). Delevatti et al. (37) reported that there is a relationship between sleep quality and quality of life in individuals with type 2 DM, and exercise training

improves both at a similar rate. A similar increase was found in the PSQI and World Health Organization (WHO) quality of life indexes with aerobic exercises lasting 12 weeks (37). Another study has shown that yoga and aerobic exercises performed for 12 weeks have positive effects on PSQI in individuals with type 2 DM (38). Similar to the literature, sleep quality was also examined in this study and significant results were recorded in sleep quality in individuals with type 2 DM with 12-week exercise training.

The strength of our study is that the exercise program is combined and continued for 12 weeks. It has been proven that combined exercises have positive effects on HbA1c, fasting and postprandial glucose levels, and insulin sensitivity before, but studies examining the effects on balance, muscle strength, and sleep quality are limited. The limitation of our study is the absence of a control group. More meaningful results can be achieved by adding a control group in future studies.

CONCLUSION

It was observed that the combination of long-term aerobic and strengthening exercise improved glucose level, muscle strength, balance, and sleep quality in individuals with type 2 DM. A structured exercise program, which includes strengthening and aerobic exercises would be beneficial in developing the most effective and appropriate exercise prescriptions in terms of exercise efficiency and sustainability for individuals with type 2 diabetes in clinics. It would manage overall symptoms, enhance functionality and quality of life, and reduce disease-related health costs.

Ethics Committee Approval: The study was approved by the Non-invasive Clinical Researches Ethics Committee of İstanbul Medipol University (09.12.2021, 1262).

Conflict of Interest: None declared by the authors.

Financial Disclosure: None declared by the authors.

Acknowledgments: None declared by the authors.

Author Contributions: Idea/Concept: MYM, MB; Design: MYM, MB; Data Collection/Processing: MYM; Analysis/Interpretation: MYM, MB; Literature Review: MYM, MB; Drafting/Writing: MYM, MB; Critical Review: MYM.

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