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Original Article

Effects of Home-Based Aerobic Exercise Training on Glycemic Control and Lipid Profiles in Patients with Prediabetes and Type 2 Diabetes: A Randomized Controlled Study

Ev Tabanlı Aerobik Egzersiz Eğitiminin Prediyabet ve Tip 2 Diyabetli Hastalarda Glisemik Kontrol ve Lipid Profili Üzerine Etkileri: Randomize Kontrollü Çalışma

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ABSTRACT

Objective: Diabetes is an important health condition; in recent years, its prevalence has increased dramatically. This study aimed to evaluate the effects of home-based aerobic exercise training on glycemic control and lipid profiles in patients with prediabetes and type 2 diabetes.

Material and Methods: This study included a total of 65 patients with ages between 38 and 66 years. The participants were divided into prediabetes exercise group (group I, $n = 17$), prediabetes control group (group II, $n = 17$), type 2 diabetes exercise group (group III, $n = 17$), and type 2 diabetes control group (group IV, $n = 14$). Home-based aerobic exercise training was suggested to all individuals in exercise groups (30 min, 60% of maximum heart rate [220 beats/min minus their age], 3 days per week) by a physiotherapist.

Results: Among the patients, 61.5% were male and 38.5% were female. Participants' sociodemographic characteristics, such as age, sex, and body mass index values, were similar ($P > .05$). After follow-up, the fasting plasma glucose (FPG) and high-density lipoprotein cholesterol (HDL_C) values were different in group I ($P < .05$). However, there were no differences in group II ($P > .05$). Hemoglobin A1c, HDL_C, FPG, and postprandial plasma glucose variables showed significant differences in group III ($P < .05$). There was a significant difference only in FPG levels in group IV ($P < .05$).

Conclusion: Home-based exercise program is important for improving the patient's self-control of diabetes. However, patients need physiotherapy counseling for sustainable home-based exercise training.

Keywords: Aerobic exercise, prediabetes, type 2 diabetes

ÖZ

Amaç: Diyabet son yıllarda prevelansı artan önemli önemli bir sağlık sorunudur. Bu çalışma, prediyabet ve tip 2 diyabetli hastalarda evde aerobik egzersiz eğitiminin glisemik kontrol ve lipid profilleri üzerindeki etkilerini değerlendirmeyi amaçlamaktadır.

Gereç ve Yöntem: Bu çalışmaya 38-66 yaş aralığında 65 hasta dahil edildi. Katılımcılar; prediyabet egzersiz grubu (grup I, $n = 17$), prediyabet kontrol grubu (grup II, $n = 17$), tip 2 diyabet egzersiz grubu (grup III, $n = 17$) ve tip 2 diyabet kontrol grubu (grup IV, $n = 14$) olarak ayrıldı. Egzersiz grubuna dahil edilen her hastaya fizyoterapist tarafından aerobik ev egzersiz eğitimi önerildi (Maksimum kalp hızının (220-yaş) %60'ı oranında haftada 3 kez 30 dakika).

Bulgular: Hastaların %61,5'i erkek, %38,5'i kadındı. Katılımcıların yaş, cinsiyet ve vücut kitle indeksi değerleri gibi sosyodemografik özellikleri benzerdi ($P > ,05$). Tedaviden sonra grup I'e dahil edilen hastaların açlık kan şekeri (AKŞ) ve yüksek yoğunluklu lipoprotein (HDL-C) değerlerinde anlamlı farklılık saptandı ($P < ,05$). Grup II 'de ise değerlendirilen parametrelerde anlamlı bir farklılık yoktu ($P > ,05$). Grup III' e dahil edilen hastaların hemoglobin A1c (HbA1c), HDL_C ve AKŞ ve tokluk kan şekeri değişkenlerinde anlamlı farklılıklar bulundu ($P < ,05$). Grup IV'de ise sadece açlık kan şekeri düzeylerinde anlamlı bir fark vardı ($P < ,05$).

Sonuç: Evde egzersiz programı, hastanın diyabeti kendi kendine kontrol etmesini iyileştirmek için önemlidir. Bununla birlikte, hastaların sürdürülebilir ev tabanlı egzersiz eğitimi için fizyoterapi danışmanlığına ihtiyacı vardır.

Anahtar kelimeler: Aerobik egzersiz, prediyabet, tip 2 diyabet

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Introduction

Diabetes is a metabolic disease defined as chronic hyperglycemia.[1] The prevalence of diabetes worldwide has increased in recent years.[2] The global prevalence of type 2 diabetes among adults is estimated to increase from 8.8% in 2017 to 9.9% in 2045.[3]

Prediabetes is generally defined as impaired fasting glycemia (IFG) in the literature, adhering to the American Diabetes Association (ADA) terminology. However, the International Diabetes Federation and the World Health Organization prefer impaired glucose tolerance (IGT) and intermediate hyperglycemia, respectively.[4] IFG and IGT are both characterized by insulin resistance, impaired insulin secretion, and affected fatty acid metabolism.[5] It has been reported that 318 million adults have glucose tolerance disorder, and this number is supposed to reach 481 million in 2040.[6]

Prediabetes is an important risk factor of type 2 diabetes. Diabetes may be postponed in some patients with prediabetes by maintaining their plasma glucose levels within normal limits, and there is a moderate-level evidence that diet and physical activity reduce the risk of type 2 diabetes in people with IGT.[6,7]

Aerobic exercise is one of the treatment methods for the management of diabetes.[8,9] It is often preferred because it improves insulin sensitivity and mitochondrial function.[10] Exercise may increase insulin sensitivity by antagonizing the insulin resistance mechanism. Low-intensity aerobic exercise stimulates glucose intake through mechanisms independent of insulin during muscle contraction by increasing glucose transporter type 4 (GLUT4) expression. In this way, it makes the skeletal muscles sensitive to insulin and increases glucose intake after exercise.[11] With the reduction in visceral fat caused by chronic exercise, the secretion of proinflammatory cytokines and chemokines from adipose tissue decreases. Thus, chronic exercise also provides strong anti-inflammatory effects.[12]

Home-based exercise is alternative exercise training for the patients who cannot attend organized rehabilitation training.[13] Recent studies have found that home-based exercise training is safe and effective in improving cardiopulmonary and functional capacities and quality of life.[14,15] In addition, home exercise training is important for improving patient self-care and diabetes control. However, how to encourage patients to adhere to exercise training is a challenge.[16]

There are many studies in the literature investigating the effects of exercise in diabetic patients.[17,18] However, there is little evidence about the effects of home-based exercise in the management of diabetes. Therefore, this study evaluated whether home-based exercise training could improve the glycemic control and lipid profile in patients with prediabetes and type 2 diabetes.

Material and Methods

This research was planned as a randomized controlled study and carried out in the Department of Endocrinology and Metabolism of Inonu University. The protocol of this study was evaluated with respect to the Consolidated Standards of Reporting Trials guidelines.[19] The ethical permissions and consents that were required for the study were obtained from Malatya Clinical Research Ethics Committee (approval number: 2019/71). All the participants provided written informed consent. A computer-generated equal allocation ratio (1:1) was produced, and random assignment to the groups was performed using our developed software.[20]

Patients who have not participated in the aerobic exercise training for at least 3 months and diagnosed with prediabetes and type 2 diabetes according to the ADA criteria were included in the study.[1] Participants with a history of lower extremity trauma in the past 6 months, advanced nephropathy, retinopathy, malignity, rheumatic or degenerative disease that would prevent walking, severe hypoglycemia, assistive device usage, anemia, or cardiac disease and cerebrovascular accident were excluded.[21] Therefore, 88 patients were included in this study, but 65 participants completed study. Participants were divided into prediabetes exercise group (group I, $n = 17$), prediabetes control group (group II, $n = 17$), type 2 diabetes exercise group (group III, $n = 17$), and type 2 diabetes control group (group IV, $n = 14$). The flowchart is shown in Figure 1.

Sociodemographic characteristics of the patients and their diagnostic information (secondary outcome measures) regarding the diagnosis and treatment process were collected using a descriptive questionnaire. Before the implementation of the study, the biochemical variables of the participants in the control and exercise groups were recorded. The biochemical analyses (primary outcome measures) of the patients were carried out after a fasting period of 12 h. The patients were followed up for examination 12 weeks later, and their biochemical variables were re-evaluated.

Control group protocol

During the study, patients in the control groups were instructed to maintain their usual physical activity and diets. In this process, they were asked not to make any changes in the use of their medication.

Exercise group protocol

The patients in the exercise groups were instructed to maintain their usual diets. They were asked not to make any changes in medications. The program was given by warm-up (5 min) before each session, which was followed by cool down (5 min) after the session. The warm-up and cool down protocols were given as walking in place and stretching. Stretching included upper and lower body flexibility exercises. The program included walking for 30 min, 3 times per week, for 12 weeks. They were asked to begin the exercise with periods of 10 min. A 10-min increment in duration was prescribed every 3 weeks until 9 weeks. The intensity was prescribed according to the maximum heart rate.[22] The maximal heart rate index was estimated as: 220−age.[23] The patients were taught about pulse measurement from the radial artery to ensure that they walked at the right heart rate. Exercise intensity was chosen to correspond to 60% of the maximal heart rate, determined for each patient during the exercise described earlier.[22] During the exercise, they were instructed to stop exercising when there was headache,

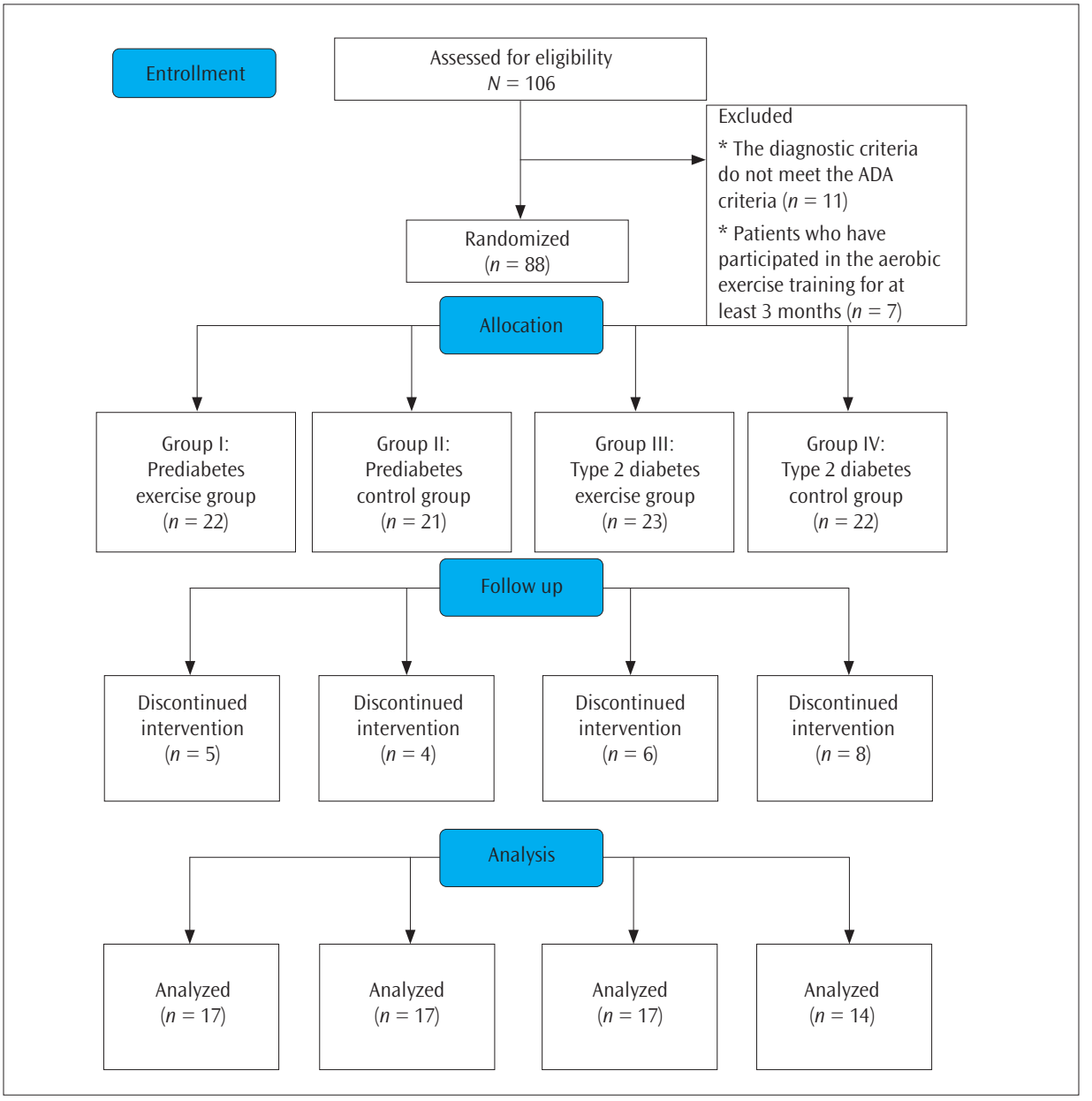

Figure 1. The Consolidated Standards of Reporting Trials Flow Diagram of the 4 Study Groups[19]

palpitations, light headedness, or hunger. The patients were asked to drink enough water during and after exercise and to exercise with a family member or friend. A WhatsApp group was formed for the patients who approved the implementation. Exercise training of patients was given progressively, and daily follow-up of patients was performed with the WhatsApp group. The researcher physiotherapist called the patients every evening at 10 PM and questioned whether the patients did it. Thus, the patients were supported in relation to the exercises.

Statistical analysis

In this study, the calculated power (1-beta) was approximately 1 considering a type I error rate (alpha) of 0.05, sample size of 17, and effect size of 3.04 according to the post-hoc power analysis.[24] For descriptive statistics, the quantitative data are summarized using the mean±standard deviation values, whereas the qualitative data are expressed in terms of frequencies and percentages. The quantitative data were tested for normal distribution using the Shapiro-Wilk test and were not normally distributed ($P < .05$). Differences between the independent samples and paired samples were compared using the nonparametric Mann-Whitney U test and Wilcoxon test, respectively. The pre-and post-follow-up score differences with respect to the exercise groups were compared using the Kruskal-Wallis H test after the Bonferroni-corrected Mann-Whitney U test. The Pearson chi-square test was used in the analysis of categorical variables. Statistical significance was determined at $P < .05$. The data were analyzed using The Statistical Package for Social Sciences version 25.0 software (IBM Corp.; Armonk, NY, USA).

Table 1. Distribution of Demographic Characteristics Between Groups

	Group I	Group II	Group III	Group IV	*P*
	Median (range)	Median (range)	Median (range)	Median (range)	
Age, years	58.50 (26.00)	51.00 (26.00)	55.00 (29.00)	49 (38.00)	0.732[a]
BMI, kg/m^2	28.9 (12.2)	27.4 (32.9)	29.1 (21.9)	31.2 (18.7)	0.684[a]
Sex	***n* (%)**	***n* (%)**	***n* (%)**	***n* (%)**	
Female	4 (28.6)	6 (35.3)	7 (41.2)	8 (47.1)	0.745[b]
Male	10 (71.4)	11 (54.7)	10 (58.8)	9 (52.9)	

Abbreviations: BMI, body mass index. [a]Kruskal Wallis; [b]Pearson chi-square

Table 2. Comparison of Pre- and Post-Follow-Up Scores for Groups I and II

Variables	Group I (*n* = 17), median (range)	Group II (*n* = 17), median (range)	*P*[a]
HbA1c			
Pre-follow-up	6.05 (1.28)	6.00 (4.10)	0.734
Post-follow-up	6.00 (2.50)	6.00 (3.90)	0.952
P[b]	0.875	0.795	
FPG			
Pre-follow-up	121 (105.00)	110.00 (168.00)	0.030*
Post-follow-up	109.50 (78.00)	108.00 (132.00)	0.525
P[b]	0.007*	0.758	
PPG			
Pre-follow-up	210 (201.00)	177 (217.00)	0.217
Post-follow-up	145 (272.00)	178 (221.00)	0.159
P[b]	0.133	0.740	
LDL_C			
Pre-follow-up	123.40 (99)	116.00 (95.00)	0.937
Post-follow-up	116.95 (121.30)	122.00 (137.00)	0.228
P[b]	0.953	0.236	
HDL_C			
Pre-follow-up	42 (40.80)	43.60 (44.60)	0.525
Post-follow-up	53.15 (113.60)	45.00 (82.20)	0.03*
P[b]	0.002*	0.813	
Triglyceride			
Pre-follow-up	139.00 (428.00)	127.00 (296.00)	0.662
Post-follow-up	176.00 (168.00)	135.00 (518.00)	0.436
P[b]	0.767	0.236	
Total cholesterol			
Pre-follow-up	188.50 (74.00)	188.00 (149.00)	0.721
Post-follow-up	186.50 (71.00)	193.00 (127.00)	0.451
P[b]	0.722	0.227	

*$P < .05$. aMann–Whitney U test; bWilcoxon signed-rank test. *Abbreviations*: HbA1c, hemoglobin A1c; FPG, fasting plasma glucose; PPG, postprandial plasma glucose; LDL_C, low-density lipoprotein cholesterol; HDL_C, high-density lipoprotein cholesterol

Results

Of the patients, 61.5% were male and 38.5% were female and their mean age was 52.43 ± 8.6 years. Their mean body mass index (BMI) value was 29.92 ± 5.20 kg/m^2. Participants' sociodemographic characteristics, such as age, sex, and BMI value, were similar (Table 1).

Biochemical variables of groups I and II were similar before and after 12 weeks of follow-up ($P > .05$). Differences were found in fasting plasma glucose (FPG) and high-density lipoprotein cholesterol (HDL_C) values of the participants in group I after follow-up ($P < .05$). Table 2 shows that the values of group II before and after follow-up were similar ($P > .05$).

Only hemoglobin A1c (HbA1c) value differed between the groups III and IV after follow-up ($P < .05$). Other biochemical variables were similar ($P > .05$). Significant improvement was observed in HDL_C, HbA1c, FPG, and postprandial plasma glucose (PPG) values in group III ($P < .05$). However, low-density lipoprotein cholesterol (LDL_C), triglyceride, or total cholesterol values were similar ($P > .05$). Significant improvement was found only in FPG values of patients in group IV ($P < .05$) (Table 3). Comparison of the pre-and post-follow-up score differences with respect to the groups is presented in Table 4. The groups that showed pre-and post-follow-up score differences were groups I and III.

Discussion

Diabetes is a major public health problem. The benefits of exercise in preventing and treating type 2 diabetes are widely recognized.[18] This study demonstrated that home-based aerobic exercise training resulted in significant improvements of glycemic control and lipid profile in patients with prediabetes and type 2 diabetes. All variables were observed to be improved for exercise groups (groups I and III) as a result of home-based exercise training. On comparing the exercise groups with the control groups, significant differences were found in HbA1c, HDL_C, FPG, and PPG values in patients with type 2 diabetes and in FPG and HDL_C values in patients with prediabetes.

Although a significant part of insulin resistance and secretion is related to genetic factors, it may be noticeably transformed by environmental and behavioral regulation. Several studies in the literature have shown that exercise training may be useful in preventing and controlling diabetes and delaying its related complications.[25,26] Studies investigating the effectiveness of exercise in diabetes control have reported that clinically significant improvements were observed in glucose control in both individuals with insulin resistance and those with type 2 diabetes by increasing physical activity levels, and the mean improvement level in HbA1c varied from -0.4% to 0.6%.[27-29] However, no data regarding the effectiveness of individualized exercise training could be found.

Maiorana et al.[30] have performed a study with 16 patients using an 8-week aerobic exercise training, and as a result, they determined that peak oxygen intake, exercise test time, and HbA1c

and FPG levels decreased. It has been reported in the literature that exercise has positive effects on diabetes management.[26,27]

Kucukarslan et al.[31] have evaluated the effect of combined resistance and home exercise, which was planned for 8 weeks of program in patients with type 2 diabetes, and this study showed no significant difference in plasma total, HDL_C, LDL_C, or triglycerides values for the exercise and control groups. However, HbA1c was found to be lower in the exercise groups.

Table 3. Comparison of Pre- and Post-Follow-Up Scores for the Groups III and IV

Variables	Group III (n = 17), median (range)	Group IV (n = 14), median (range)	P [a]
HbA1c			
Pre-follow-up	9.10 (8.40)	7.70 (5.50)	0.070
Post-follow-up	7.10 (7.10)	8.30 (6.70)	0.005*
P [b]	0.001*	0.235	
FPG			
Pre-follow-up	162.00 (572.00)	177 (209)	0.890
Post-follow-up	132.00 (154.00)	149 (134)	0.361
P [b]	0.013*	0.026*	
PPG			
Pre-follow-up	223.00 (496.00)	224.00 (195.00)	0.544
Post-follow-up	189.00 (214.00)	247.00 (238.00)	0.062
P [b]	0.002*	0.218	
LDL_C			
Pre-follow-up	111.20 (155)	126 (82)	0.398
Post-follow-up	138.30 (157.10)	112 (120)	0.249
P [b]	0.101	0.669	
HDL_C			
Pre-follow-up	38.70 (25.50)	43.40 (48.80)	0.056
Post-follow-up	41.50 (46.10)	45.00 (58.00)	0.730
P [b]	0.007*	0.619	
Triglyceride			
Pre-follow-up	220.00 (972.00)	187.00 (331.00)	0.361
Post-follow-up	179.00 (3121.00)	167.00 (217.00)	0.851
P [b]	0.507	0.177	
Total cholesterol			
Pre-follow-up	203.00 (111.00)	194.00 (113.00)	0.945
Post-follow-up	196.00 (348.00)	210.00 (124.00)	0.707
P [b]	0.666	0.308	

*$P < .05$. [a]Mann–Whitney U test; [b]Wilcoxon signed-rank test. *Abbreviations*: HbA1c, Hemoglobin A1c; FPG, Fasting plasma glucose; PPG, postprandial plasma glucose; LDL_C, low-density lipoprotein cholesterol; HDL_C, High-density lipoprotein cholesterol

Van Dijk et al.[32] have observed that 24-h glycemic control improved with moderate-intensity exercise in patients with type 2 diabetes. Among the examined variables, only HbA1c was found to be related to the degree of response to the treatment.

In our study, similar to the literature, significant improvement in the HbA1c values was achieved in patients with type 2 diabetes. Regular aerobic exercise is known to increase skeletal muscle capitalization, blood flow, and GLUT4 levels.[33] In addition, in this study, a significant difference was found in the HDL_C, FPG, and PPG values. Exercise program is effective for lipid profile in diabetes. The effect of regular exercise on lipid and lipoprotein metabolism in diabetes is assumed to be owing to its anti-atherogenic effects.[34] However, it has been reported that the intensity, duration, and frequency of exercise are also important. We concluded that home-based exercise training planned under the guidance of physiotherapists is important in self-control of diabetes. Community-based diabetes training more commonly incorporates promoting exercise at home.[35]

Prediabetes that is not controlled is a significant risk factor of type 2 diabetes. Sedentary lifestyles and physical inactivity prevent diabetes from being controlled. The plasma glucose levels of patients with prediabetes should be maintained in the normal range. In this context, it is highly important to increase the physical activity levels of patients with prediabetes.[36]

In a multicenter retrospective study that included patients with prediabetes and diabetes, the group that took part in lifestyle modification and the group that received conventional treatments were compared on the basis of their levels of exercise, HbA1c, fasting glucose, blood pressure, and blood lipid in a 1-year interval, and no statistically significant difference was found.[37] The reason for this lack of significant difference may be that the authors did not plan individualized aerobic exercise training.

The positive effects of exercise in patients with prediabetes were also observed in our study. In this study, all variables were observed to be improved for the prediabetes group (group I),

Table 4. Comparison of Pre -and Post- Follow-Up Score Differences with Respect to Groups

	Experimental groups							
	Group I		Group II		Group III		Group IV	
Variables	Median	Range	Median	Range	Median	Range	Median	Range
HbA1c	0.00[c]	2.80	0.10	1.20	1.80[a,b]	6.70	–0.50	2.60
FPG	10.00	83.00	–1.00	53.00	21.00[a]	563.00	21.00	151.00
PPG	29.00	262.00	5.00	104.00	44.00[b]	321.00	–14.00	238.00
LDL_C	–1.55	117.00	–10.00	171.00	–10.00	103.20	0.00	90.00
HDL_C	–7.55[a,b]	94.00	0.40	63.80	–5.00	46.30	–2.20	37.00
Triglyceride	–7.50	337.00	–3.00	265.00	20.00	2779.00	13.00	189.00
Total Cholesterol	–1.50	45.00	–6.00	81.00	–5.00	99.00	–4.00	110.00

[a]significantly different from group II; [b]significantly different from group IV; [c]significantly different from group III using the Bonferroni-corrected Mann–Whitney U test after significant Kruskal–Wallis H test ($P < .05$).

as a result of 12 weeks of training. However, significant differences in comparison with the control groups were found only in the FPG level and HDL_C in patients with prediabetes. Definite results can be achieved from larger sample size or higher duration of the exercise training. Skeletal muscle adaptations related to exercise are important in the management of diabetes.[38] Maintaining muscle mass is essential for lipid control and improvement of metabolic syndrome.[39]

The groups that showed pre- and post-follow-up score differences were groups I and III. Our study provides evidence for involving physiotherapy-guided home exercise training in the prevention and treatment of diabetes.

Study limitations

The lack of evaluation of physical activity levels of patients before training and fatigue levels during training is a limitation of this study. Another limitation of our study was that no heart rate measurement device was used for target heart rate monitoring.

Conclusion

Diabetes is one of the most significant health problems. Its burden on the patient and related healthcare expenditures is high. Although the effect of home-based exercise in the management of diabetes has been the topic of several studies, few studies have reported its positive effects.[11,23] We concluded that exercise training may be useful in preventing and controlling diabetes and delaying its related complications. Our study demonstrated that home-based exercise training is important for improving the patient's self-control of diabetes. However, patients need physiotherapy counseling for sustainable home-based exercise training. Regarding this topic, there is a need for more advanced studies that include individualized and sustainable exercise training with a larger group of participants. In addition, we think that the factors that will affect the results of home-based exercises in diabetes management (such as physical activity levels, smoking and alcohol use, eating habits, drugs used, and the anxiety-depression levels of the patients) should be questioned in future studies. In contrast, target heart rate monitoring should be performed with more objective methods for future studies. We think that planning studies evaluating the effects of different types of exercise on diabetes and comparing them with the results obtained in our study will be innovation in the literature.

Ethics Committee Approval: Ethics committee approval was received for this study from the Malatya Clinical Research Ethics Committee (2019/71).

Informed Consent: All patients included in the study were informed about the study and signed an informed voluntary consent form.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - F.O., M.H.K.; Design - F.O., B.E.; Supervision - I.S.; Resources - F.O., B.E.; Materials - F.O., I.S.; Data Collection and/or Processing - F.O., M.H.C.; Analysis and/or Interpretation - C.C.; Literature Search - F.O., B.E.; Writing Manuscript - F.O., M.H.K.; Critical Review -I.S., C.C.

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Hasta Onamı: Çalışmaya dahil edilen tüm hastalar çalışma hakkında bilgilendirildi ve bilgilendirilmiş gönüllü onam formunu imzaladı.

Hakem Değerlendirmesi: Dış bağımsız.

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