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Research Article

Effect of Pilates on Body Composition and Some Biochemical Parameters of Women with Type 2 Diabetes on a Low-Carbohydrate or High-Complex-Carbohydrate Diabetic Diet

Nazli Batar [1,*], Seda Kermen [2], Sezen Sevdin [1], Aybuke Ersin [3], Sevil San [4], Mustafa Genco Erdem [5], Halime Pulat Demir [6] and Duygu Guclu [7]

[1]Nutrition and Dietetic Department, Istanbul Kultur University, Istanbul, Turkey
[2]Health Sciences Institute, Istanbul University, Istanbul, Turkey
[3]Occupational Therapy Department, Atlas University, Istanbul, Turkey
[4]Nutrition and Dietetic Department, Medikalpark Fatih Hospital, Istanbul, Turkey
[5]Internal Medicine Department, Beykent University, Istanbul, Turkey
[6]Nutrition and Dietetic Department, Gelisim University, Istanbul, Turkey
[7]Nutrition and Dietetic Department, Sante Plus Hospital, Istanbul, Turkey

[*]*Corresponding author*: Nutrition and Dietetic Department, Istanbul Kultur University, Istanbul, Turkey. Tel: +90-5334133717, Email: n.batar@iku.edu.tr

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Abstract

Background: The prevalence of type 2 diabetes mellitus (T2DM) has increased dramatically in the past 30 years. The World Health Organization has prepared an action plan to stop the increase in diabetes and obesity by 2025.
Objectives: This study was conducted to assess the effect of pilates on body composition and some biochemical parameters in women with T2DM on a high-complex-carbohydrate diabetic diet or a low-carbohydrate/high-monounsaturated fatty acids (MUFA) diet.
Methods: This experimental study was conducted on 120 woman patients with T2DM, referring to the Fatih Medical Park Hospital's Internal Medicine Department, Istanbul, Turkey, between December 2018 and June 2019. Participants were divided into 4 groups and were followed up for 12 weeks. The mean participants' age was 41.67 ± 3.83 years. The first group received a low-carbohydrate and high MUFA (LC, MUFA) diet, the second group received a low-carbohydrate and a high-MUFA diet and did pilates (LC, MUFA + PL), the third group received a higher complex carbohydrate (HCC) diet, and the fourth group took the HCC diet and did pilates (HCC + PL).
Results: According to the applied intervention method, there were significant differences between the preliminary and final measurements of body mass index, body fat percentage, muscle mass, and fasting blood glucose, insulin, HbA1c, total cholesterol, high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglyceride (TG) values ($P < 0.05$). In this study, only an increase in body muscle composition of the women in the LC, MUFA + PL group was found significant ($P < 0.05$). The highest decrease in body fat ratio was determined again in the LC, MUFA + PL group ($P < 0.05$). HDL levels of the women who did pilates increased significantly than other groups ($P < 0.05$).
Conclusions: In the treatment of diabetes, the patient should be evaluated with a multidisciplinary team. Diet and exercise are important non-pharmacological interventions in the treatment of diabetes.

Keywords: Diabetes, Diet, Low-Carbohydrate, High-Complex-Carbohydrate, Diabetic Diet

1. Background

Diabetes is a chronic metabolic disease, in which the organism cannot benefit from carbohydrates, fats, and proteins due to insulin deficiency or defects in insulin effect, and requires constant medical care (1). The most common type of diabetes is type 2 diabetes mellitus (T2DM), mostly seen in adults, characterized by insulin resistance or insufficiency. The prevalence of T2DM has increased dramatically in the past 30 years. The World Health Organization (WHO) has prepared an action plan to stop the increase in the number of cases with diabetes and obesity by 2025 (2).

The objectives of medical nutrition therapy in diabetes are providing optimal metabolic results, preventing complications of diabetes, changing lifestyle and behavior, and maintaining these changes. It is recommended that the carbohydrate content of the diet should contain 20 - 35 g pulp providing 44 - 46% of the energy intake of individuals according to the targeted blood glucose and lipid levels. Protein recommendation should be planned to be 1 - 1.5 g/kg.day or 15 - 20% of the total daily intake for diabetics without kidney or liver disease (3). The energy of the diet's fat content should be 20 - 35% of the total calories from fat. In the pattern of dietary fat, trans fat and saturated fat intake should be limited, whereas monounsaturated fatty acids (MUFAs) and omega 3 intakes should be increased (3, 4). To prevent the risk of chronic diseases, increasing the consumption of fruits, vegetables, and whole-grain products, and limiting the amounts of simple carbohydrates and saturated fats are suggested (5). The superiority and positive effects of the Mediterranean diet on chronic diseases have been proved by numerous studies. The Mediterranean diet also reduces the risk of T2DM, obesity, and cancer (6, 7). One of the most important components of the Mediterranean diet is olive oil. In a typical Mediterranean diet, it is generally recommended to consume 25 - 50 mL/day olive oil. It is known that the phenolic components in olive oil are higher than other types of oils. Phenolic compounds in olive oil have anti-inflammatory and inhibiting effects on platelet deposition (5). Also, olive oil improves glucose metabolism due to its monounsaturated fat content and increases fat oxidation and thermogenesis. Thus, it is assumed that olive oil can be added to the diet for weight loss (8).

Exercise decreases insulin resistance and insulin requirement by increasing insulin sensitivity in tissues and is used as a non-pharmacological intervention in T2DM treatment (9). It contributes to the improvement of metabolic control by providing blood glucose regulation (1, 10, 11). The efficacy of exercise is closely related to muscle contraction during activity, which leads to an increase in insulin sensitivity and a decrease in insulin resistance that stimulate glucose uptake and clearance by lowering inflammation and promoting physical activity (9). Physical activity for 150 min per week plays an important role in preventing diabetes. It is recommended that type 2 diabetic adults have resistance exercises every two days and flexibility and balance exercises, such as yoga and pilates, 2 - 3 times a week (3). It is extremely important to raise awareness in healthcare professionals and patients about other physiological changes, especially possible blood glucose level changes, which can be caused by exercise to prevent patients from damages caused by physical activity (12).

Several health benefits have been proposed for patients with T2DM or those at high risk following structured physical activity protocols, such as a physical exercise (PE)-based treatment. PE is directly correlated with a reduction in T2DM risk with its ability to regulate glucose metabolism and hemoglobin A1c (HbA1c) levels. Besides, PE in patients with T2DM can promote musculoskeletal health, decrease HbA1c levels, trigger weight loss, prevent cognitive decline, and reduce symptoms of depression and anxiety, thereby improving global functioning and quality of life. As a result, PE-based treatments can prevent both morbidity and all mortality causes in these patients (13).

Pilates was developed by Joseph Pilates at the beginning of the 1900s. The key points of this exercise model are speed control, and movement quality and precision (14). Pilates is a type of body conditioning incorporating the principles of concentration, control, precision, and breathing. Several studies have shown the positive effects of pilates on body mass index (BMI), flexibility, endurance, balance, perception of functionality, physical self-concept, and perception of health status (14-21).

2. Objectives

This study was conducted to observe the effect of pilates on body composition and some biochemical parameters in women with T2DM who are on a high-carbohydrate diabetic diet or a diet with low carbohydrate and high monounsaturated fatty acids.

3. Methods

This experimental study was conducted on 120 women with T2DM, referring to the internal medicine polyclinics of Fatih Medikal Park Hospital, Istanbul Turkey, which is a private university hospital, between December 2018 and June 2019.

The statistical population of this study included 215 diabetic patients who applied to the clinic between December 2018 and June 2019, of whom 81 cases were excluded from due to gender and 14 woman were excluded with respect to the exclusion criteria of the study. The remaining 120 patients who maintained regular diet and medical follow-ups were divided into 4 groups according to the planned exercise and diets by simple random sampling (www.random.org). Participants were randomly allocated to the pilates exercise group or diet group (30 participants per group).

The Ethical Review Committee of Istanbul Gelisim University approved the study protocol (approval code: 2017-13/2017-12-14). All participants provided written consent in accordance with the Declaration of Helsinki. The principal researcher received the consent forms of the volunteers who agreed to participate in the study. The participants' age in both groups was between 18 and 65 years and did not participate in any other regular physical exercise programs. Type 1 diabetes, women with BMI < 25 kg/m^2, the patients with acute complications of diabetes (diabetic ketoacidosis, hypoglycemia, hyperglycemic hyperosmolar nonketotic coma) and the patients who could not perform the exercises were not included in this study (see Figure 1 for the flow diagram of the patients). During this study, patients in groups continued their prescribed medical and dietary treatments.

3.1. Dietary Program

Body fat analysis of female patients diagnosed with T2DM was performed using regularly calibrated Tanita (model BC-418; Tanita Corp. Tokyo, Japan) before and 12 weeks after the study. The accuracy rate of Tanita BC-418 has reported high in measuring the body fat distribution (22, 23). Diabetic diets recommended to patients for 12 weeks, were planned individually, considering the medications and insulin doses used by the patients. The planned diets are as follows:

Low-carbohydrate, high monounsaturated fatty acids (LC, MUFA) diet: 200 mg cholesterol, 30 g fiber, 35% carbohydrate 22.5% complex carbohydrate (oat), 15% protein, 50% fat, 33% MUFA diabetic diet. Low-carbohydrate, high monounsaturated fatty acids diet + pilates (LC, MUFA+PL): 200 mg cholesterol, 30g fiber, 35% carbohydrate 22.5% complex carbohydrate (oat), 15% protein, 50% fat, 33% MUFA diabetic diet + 12 weeks pilates. High-complex carbohydrate (HCC) diet: 200 mg cholesterol, 30 g fiber 60% carbohydrate 47% complex carbohydrate (oat), 15% protein, 25% fat, 10% MUFA diabetic diet. High-complex carbohydrate diet + pilates (HCC + PL): 200 mg cholesterol, 30 g fiber 60% carbohydrate 47% complex carbohydrate (oat), 15% protein, 25% fat, 10% MUFA diabetic diet + 12 weeks pilates. Campbell and Rains pointed out the protein quality in the diet. It was emphasized that adequate protein consumption may protect muscle mass, providing a feeling of satiety that may have positive effects on glycemic control (24). In this study, the protein ratio was planned as 15% of the energy in all diet types. Daily fat intake should be 20% - 35% of the total calories from fat for people with diabetes. Trans fat and saturated fat intake should be limited and the diet should be enriched with MUFAs and omega 3 (3, 4). Schwingshackl et al. (25), in their meta-analysis, stated that the Mediterranean diet has positive effects on blood glucose regulation. They compared the effects of a diabetic high-monounsaturated-fat/low-carbohydrate with a high-complex-carbohydrate diet were compared (25).

3.2. Biochemical Parameters

The biochemical parameters, such as fasting blood glucose (FBG), glycosylated hemoglobin (HbA1C), total cholesterol (total-chol), high-density lipoprotein (HDL), low-density lipoprotein (LDL), triglyceride (TG), and fasting insulin of women with T2DM who participated in the study were evaluated before and 12 weeks after the study. Biochemical parameters were determined after an 8-hour fasting period.

3.3. Training Program

The patients were trained for diaphragmatic breathing by physiotherapists before leading the training program since it has a positive effect on glycemic parameters (17). The training program lasted 12 weeks during the summer of 2019. The program was conducted by a certified pilates physiotherapist as three 60-min sessions per week at middle intensity. Each session started with checking body state (pelvis and spinal column), controlling the breath, and standing posture, all were trained on the first day. After 10 min of warm-up, basic pilates training was applied for arms, legs, and trunk before 10 min of cool-down. The patients were asked to control their blood glucose during the first sessions (before, during, and after the training) and continue the training if their blood glucose level was 100 - 180 mg/dL (17).

Melo et al. (26) conducted a pilates training program on T2DM patients as three sessions per week during 12 weeks, and changes in the biochemical parameters of patients were evaluated at the 4th, 8th, and 12th weeks of training. At week four, the changes in fasting and postprandial blood glucose were found significant; however, the change in HbA1c was found significant at week twelve. Therefore, pilates training was planned for 12 weeks in this study.

3.4. Statistical Analyses

Prior to the analyses, the data collected from the participants were coded to the software. The mean and standard deviation were used to define the groups collected before and after the measurements of variables. Two-way repeated-measures ANOVA analysis was used to determine the difference between pre- and post-measurements among groups. The normal distribution of the data was confirmed by calculating skewness and kurtosis values. Mauchly's test of sphericity was conducted to test the sphericity assumption and the data did not provide the globalization assumption for all variables, and the Greenhouse-Geisser correction was made to analyze the data. The homogeneity of variances assumption was tested using Levene's test, and the values were found insignificant and the homogeneity of variance was approved. The Bonferroni test was used to find the differences between the groups. The significance value was accepted as 0.05. Data analysis was done using the JASP 0.11.1.0 program.

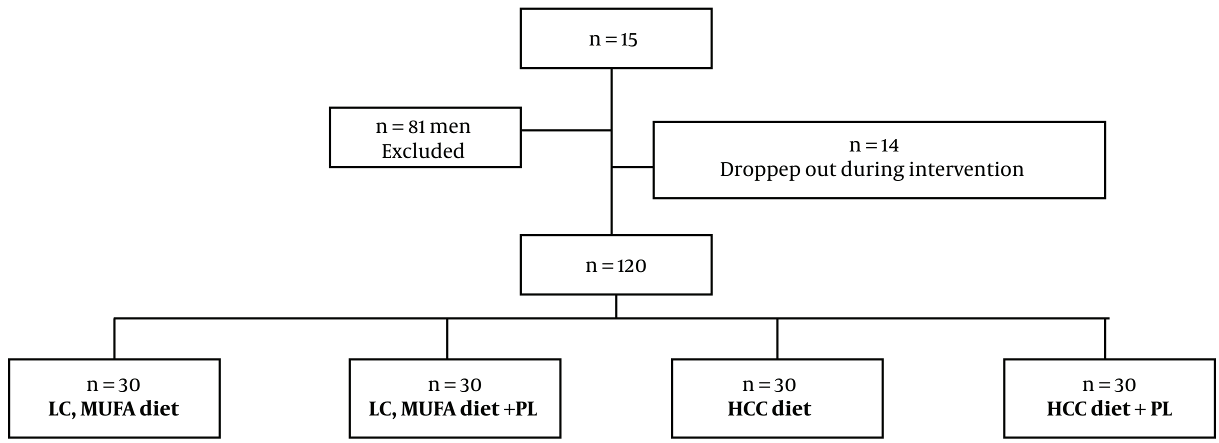

Figure 1. Flow diagram of the patients

4. Results

All the participants were women with the mean age of 41.67 ± 3.83 years (LC, MUFA: 42.23 ± 4.05 years, LC, MUFA + PL: 41.53 ± 3.43 years, HCC: 41.10 ± 2, 80 years, and HCC + PL: 41.80 ± 3.21 years). Also, 60% of the women were housewives, 20% were employees in the private sector, 12% were civil servants, and 8% were retired. Regarding their education levels, 64% were undergraduate and graduate, 25% were high school graduates, and 11% were primary school graduates.

Tables 1 and 2 represent the participants' anthropometric measurements and biochemical values by groups.

The ANOVA table, which shows the comparison of the pre- and post-measurements and the time-group interaction for the variables, is given in Table 3.

According to the table, the pre- and post-measurements for BMI, fat percentage, muscle mass, FBG, insulin, HbA1c, total cholesterol, HDL, LDL, and TG were significantly different. Regarding the time-group interactions, it was found that while the time-group interaction was not significant for TG, it was significant for other variables. Pre- and post-measurements of the participants are also shown in Figure 2.

For repeated measures ANOVA, the small effect size was $0.01 \leq \eta^2 \leq 0.06$, the medium effect size was $0.06 \leq \eta^2 \leq 0.14$, and the large effect size was $\eta^2 \geq 0.14$ (27). Accordingly, the effects of the four methods applied in the pre- and post-measurements were small for BMI, muscle mass, FBG, and HDL. The interventions were found with a moderate effect on insulin, HbA1c, LDL, and TG. The effects of interventions for fat percentage and cholesterol were remarkable. The effect of time-intervention interaction was small for BMI, muscle mass, FBG, insulin, HbA1c, total cholesterol, HDL, and LDL. The interventions were found with a medium effect regarding the time-group interaction for fat percentage. However, there was no effect regarding the time-group interaction for TG.

Table 4 presents the comparison of the pre- and post-measurements of the variables. According to this table, the HDL value increased significantly in the last measurement ($P < 0.05$). BMI, fat percentage, muscle mass, FBG, insulin, HbA1c, cholesterol, LDL, and TG values were significantly lower than the preliminary measurements ($P < 0.05$).

The results of the post-hoc test conducted to compare the groups' pre- and post-measurements of anthropometric variables are given in Table 5. According to Table 5, none of the interventions had a significant superiority in terms of final measurement values of BMI and muscle mass. In terms of fat percentage, the final measurements of the group treated with HCC were higher than the groups treated with HCC + PL and LC, MUFA + PL. The fat percentage of the HCC + PL group in the final measurement was significantly lower than the LC, MUFA group. Also, the fat percentage of the LC, MUFA group in final measurement was significantly higher than the LC, MUFA + PL group.

The comparison of the last measurements of blood values based on groups is shown in Table 6. According to Table 6, when the results were evaluated in terms of FBG, insulin, HbA1c, cholesterol, and HDL, none of the interventions had a significant superiority in terms of the final measurement values ($P > 0.05$). In terms of LDL, the final measurements of the group treated with HCC were significantly higher than the group treated with LC, MUFA + PL, and aslo the LC, MUFA group showed higher values than the LC, MUFA + PL group. TG values of the HCC-treated group in the final measurement were significantly lower than those of the LC, MUFA-treated group ($P \langle 0.05$).

Table 1. Anthropometric Measurements Results by Groups[a]

Variable	Measurement	Group	Values	Minimum	Maximum
BMI, kg/m^2	Pre	LC, MUFA	2.95 ± 1.99	26.30	35.20
		LC, MUFA + PL	29.72 ± 2.57	26.00	36.10
		HCC	30.21 ± 2.14	26.30	33.90
		HCC + PL	29.24 ± 2.24	26.30	34.00
		Total	29.67 ± 2.25	26.00	36.10
	Post	LC, MUFA	28.75 ± 1.99	25.00	34.80
		LC, MUFA + PL	27.73 ± 2.33	24.20	33.60
		HCC	29.61 ± 2.19	25.70	33.20
		HCC + PL	28.10 ± 2.25	24.80	33.00
		Total	28.55 ± 2.28	24.200	34.800
Fat, %	Pre	LC, MUFA	39.41 ± 7.43	4.10	48.80
		LC, MUFA + PL	39.48 ± 3.72	35.30	49.40
		HCC	38.83 ± 3.39	34.10	49.40
		HCC + PL	37.42 ± 2.48	33.30	45.40
		Total	38.78 ± 4.67	4.10	49.40
	Post	LC, MUFA	37.30 ± 3.66	26.70	45.10
		LC, MUFA + PL	31.02 ± 4.49	24.50	41.50
		HCC	37.10 ± 3.47	26.30	43.60
		HCC + PL	33.27 ± 3.90	24.90	43.80
		Total	34.67 ± 4.68	24.50	45.10
Muscle mass, kg	Pre	LC, MUFA	23.85 ± 2.54	18.90	28.00
		LC, MUFA + PL	23.95 ± 2.57	18.90	28.00
		HCC	24.36 ± 2.36	18.90	29.40
		HCC + PL	23.95 ± 2.57	18.90	28.00
		Total	24.03 ± 2.49	18.90	29.40
	Post	LC, MUFA	23.38 ± 2.15	19.40	29.40
		LC, MUFA + PL	24.04 ± 2.47	19.40	29.40
		HCC	23.34 ± 2.26	18.00	28.00
		HCC + PL	23.43 ± 2.46	18.50	27.60
		Total	23.55 ± 2.33	18.00	29.40

Abbreviations: HCC, high-complex carbohydrate diet; HCC + PL, high-complex carbohydrate diet + pilates; LC, MUFA: Low-carbohydrate, high monounsaturated fatty acids diet; LC, MUFA + PL, low-carbohydrate, high monounsaturated fatty acids diet + pilates.
[a]Values are expressed as mean ± SD.

5. Discussion

This study was conducted to assess the effect of pilates exercise on body composition and some biochemical parameters in women with T2DM who were on the LC/high MUFA diet and high-complex-carbohydrate diabetic diet.

Diet has an important role in the etiology of diabetes. Consuming high-carbohydrate drinks increases the risk of obesity and diabetes. Not only carbohydrates but also high-fat foods consumption have a negative effect on blood glucose regulation (28). The eating pattern recommended for diabetics is important for their blood glucose regulation. According to the Americans with Disabilities Act (ADA) 2019 guideline, the carbohydrate content of the diet should be in the form of complex carbohydrates, the diet should be rich in omega 3 and MUFA, and poor in trans and saturated fat. Daily protein consumption should be planned as 1 - 1.5 g/g.day or to provide 15% - 20% of daily energy intake (3). Based on the ADA 2015 recommendations, it is stated that 45% of energy should come from carbohydrates, 16% - 18% from proteins, and 36% - 40% from healthy fats (29). In the past five years, the protein ratio of the diet has been increased, whereas the ratio of complex carbohydrates and dietary fat has been decreased. The type and portion of carbohydrates are extremely important in diabetes. Volunteer women participating in this study were divided into four groups and followed two different diets (LC, MUFA, and HCC). According to the dietary interventions applied in this study, there was a significant difference in the final measurements of BMI and fat ratio. The increase in muscle mass of women in the LC, MUFA + PL group during the study was found significant. Low-carb foods are popular and effective in reducing cardiometabolic risks and in obesity treatment.

On the other hand, low-carb foods without exercise decrease muscle mass and osteoporosis. Perissiou et al. (30)

Table 3. The Comparison of Pre- and Post-Measurements According to the Variables

Variable	Sum of Squares	df	Mean Square	F	P	η^2
BMI, kg/m²						
Time	75.040	1	75.040	743.353	< 0.001	0.058
Time × group	17.350	3	5.783	57.290	< 0.001	0.013
Fat, %						
Time	1.013.526	1	1.013.526	85.572	< 0.001	0.163
Time × group	429.020	3	143.007	12.074	< 0.001	0.069
Muscle mass, kg						
Time	13.776	1	13.776	35.618	< 0.001	0.010
Time × group	9.163	3	3.054	7.897	< 0.001	0.007
FBG, mg/dL						
Time	9.921.490	1	9.921.490	45.605	< 0.001	0.049
Time × group	2.423.131	3	807.710	3.713	0.014	0.012
Insulin, μU/mL						
Time	5.765.732	1	5.765.732	172.748	< 0.001	0.116
Time × group	511.613	3	170.538	5.110	0.002	0.010
HbA1c, %						
Time	17.925	1	17.925	162.110	< 0.001	0.065
Time × group	2.065	3	0.688	6.224	< 0.001	0.007
CHOL, mg/dL						
Time	55.303.776	1	55.303.776	145.092	< 0.001	0.147
Time × group	7.448.039	3	2.482.680	6.513	< 0.001	0.020
HDL, mg/dL						
Time	37.557	1	37.557	9.425	0.003	0.003
Time × group	124.280	3	41.427	10.397	< 0.001	0.009
LDL, mg/dL						
Time	29.865.058	1	29.865.058	113.841	< 0.001	0.123
Time × group	3.347.283	3	1.115.761	4.253	0.007	0.014
TG, mg/dL						
Time	140.500.365	1	140.500.365	106.854	< 0.001	0.121
Time × group	2.520.132	3	840.044	0.639	0.591	0.002

assessed the effect of a combined aerobic and resistance exercise program in addition to a low-carb diet and reported that despite the improvement in cardiorespiratory fitness, the decrease in muscle mass could not be prevented. However, pilates is effective in increasing muscle mass (31). In light of this information, the obtained increase in muscle mass in the LC, MUFA + PL group in this study was consistent with other studies. The greatest decrease in fat mass was again found in the LC, MUFA + PL group. The effect of high-carbohydrate low-protein diets on excess fat mass is lower compared with energy-restricted, high-protein diets (32).

According to the diet applied, there was a significant difference in BMI and body fat rate in the final measurements. In the Savkin and Aslan study (33), the effect of pilates on body composition was evaluated in overweight and obese people. The decrease in body weight, BMI, and body fat rate of cases who performed pilates 3 times a week for 8 weeks was found significant. Another study evaluated the effects of different exercise programs applied to diabetic patients for 12 weeks on functional performance and quality of life and based on the results, exercise programs

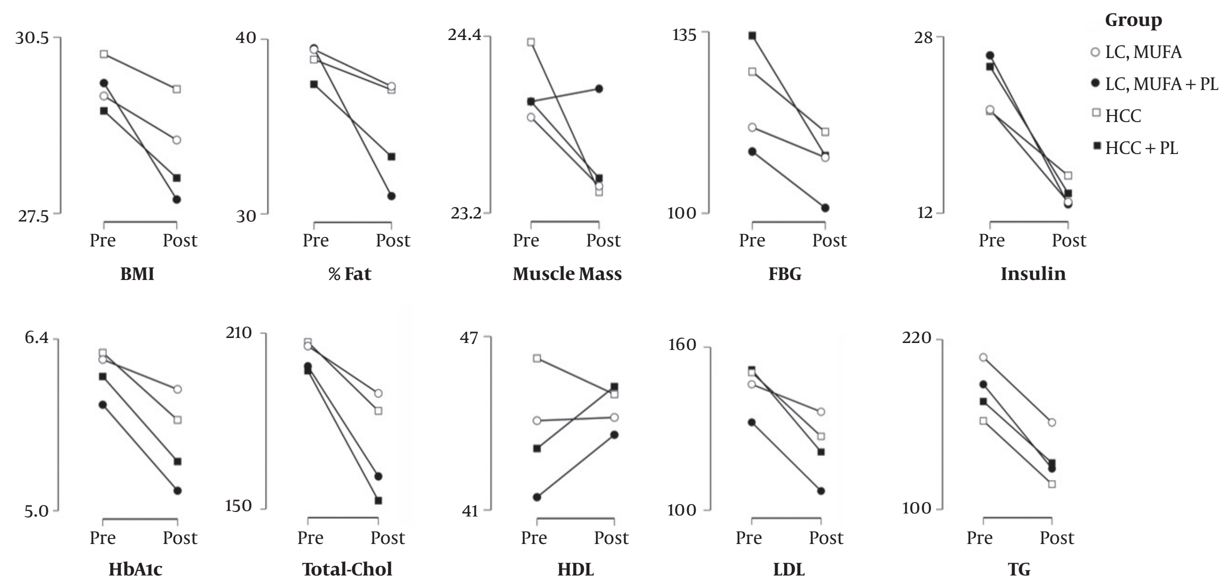

Figure 2. Preliminary and final measurements of the variables in the participants

Table 4. Post-Hoc Comparisons for the Pre- and Post-Measurements

Variable	Measurement		Difference	SE	t	P Value (Bonferroni Test)
BMI, kg/m²	Post	Pre	-1.118	0.064	-17.530	< 0.001
Fat, %	Post	Pre	-4.110	0.503	-8.179	< 0.001
Muscle mass, kg	Post	Pre	-0.479	0.087	-5.508	< 0.001
FBG, mg/dL	Post	Pre	-12.859	1.968	-6.533	< 0.001
Insulin, μU/mL	Post	Pre	-9.803	0.784	-12.511	< 0.001
HbA1c, %	Post	Pre	-0.547	0.046	-11.968	< 0.001
CHOL, mg/dL	Post	Pre	-30.360	2.690	-11.287	< 0.001
HDL, mg/dL	Post	Pre	0.791	0.287	2.760	0.007
LDL, mg/dL	Post	Pre	-22.310	2.175	-10.257	< 0.001
TG, mg/dL	Post	Pre	-48.391	4.660	-10.384	< 0.001

had positive effects on anthropometric measurements of diabetics (34). Nutrition education is the process, in which increasing dietary fiber, balanced distribution of low and high glycemic index (GI) foods in the diet, reduction of saturated and polyunsaturated fatty acids in the diet are considered, which plays a role in the treatment and prevention of T2DM and changing the eating habit of a person (35). In a study evaluating the effect of pilates on body composition for eight weeks in sedentary women, it was reported that the body fat rate of women who performed pilates decreased significantly compared with the control group (15). In this study, a significant decrease was observed in the body fat rates of all women with diabetes. However, the decrease in body fat ratio in women in the LC, MUFA + PL group was higher than in other groups. It has revealed that very low-carb diabetic diets provide more weight and fat loss. In an energy-restricted diet, low-GI, low-carb, and/or high-protein diets are thought to have additional benefits to improve glycemic control when combined with an exercise (32). In a study conducted by Saslow et al. (36), T2DM patients were recommended a diabetic diet and a very low-carb ketogenic diet following the guidelines of the ADA for 32 weeks. Diabetics who were on a very low-carb ketogenic diet lost more weight than cases on a moderate-carb diet, and it was emphasized that the subjects received recommendations regarding very low-carb ketogenic diets, while considering their eating habits and lifestyle (36). The metabolic effects of low-carb, high-fat di-

Table 5. Post-Hoc Comparisons for Anthropometric Measurements[a]

Variable	Values	t	P Value (Bonferroni Test)
BMI, kg/m²			
HCC			
HCC + PL	1.240 ± 0.571	2.170	0.192
LC, MUFA	0.790 ± 0.571	1.383	1.000
LC, MUFA + PL	1.187 ± 0.571	2.077	0.240
HCC + PL			
LC, MUFA	-0.450 ± 0.571	-0.788	1.000
LC, MUFA + PL	-0.053 ± 0.571	-0.093	1.000
LC, MUFA			
LC, MUFA + PL	0.397 ± 0.571	0.694	1.000
Fat, %			
HCC			
HCC + PL	2.623 ± 0.914	2.869	0.029
LC, MUFA	-0.385 ± 0.914	-0.421	1.000
LC, MUFA + PL	2.722 ± 0.914	2.976	0.021
HCC + PL			
LC, MUFA	-3.008 ± 0.914	-3.290	0.008
LC, MUFA + PL	0.098 ± 0.914	0.108	1.000
LC, MUFA			
LC, MUFA + PL	3.107 ± 0.914	3.397	0.006
Muscle mass, kg			
HCC			
HCC + PL	0.155 ± 0.618	0.251	1.000
LC, MUFA	0.235 ± 0.618	0.380	1.000
LC, MUFA + PL	-0.148 ± 0.618	-0.240	1.000
HCC + PL			
LC, MUFA	0.080 ± 0.618	0.130	1.000
LC, MUFA + PL	-0.303 ± 0.618	-0.491	1.000
LC, MUFA			
LC, MUFA + PL	-0.383 ± 0.618	-0.621	1.000

[a]Values are expressed as Mean ± SE.

ets have been described in many studies. Such diets may cause decreased appetite leading to weight loss and may lead to an improvement in the course of obesity-related chronic diseases (37). Similarly, in this study, the changes in BMI and body fat percentage of women on a low-carb diet were significant compared with other groups. This can be explained by low-carb diets effects in lowering appetite and thus supporting weight and body fat loss.

Hagner-Derengowska et al. (38) examined the effect of Nordic walking and pilates exercises on blood glucose and blood lipid profile in postmenopausal overweight and obese women. While there is an improvement in blood glucose and blood lipid profile of women in both exercise groups, the changes in the Nordic walking group were found to be more significant than the pilates group. Changes in lifestyle have positive effects on obesity and diabetes, and it is thought to be more effective than medical treatment (38, 39) since exercise increases insulin sensitivity in tissues, decreases insulin resistance and insulin requirements, provides blood glucose regulation, and contributes to the improvement of metabolic control (1, 10). In the current study, anthropometric measurements and changes in biochemical parameters of women who did pilates were significant compared with women who did not. This proved the positive effects of regular pilates exercises for 12 weeks on anthropometric measurements and biochemical findings and also a significant increase in HDL levels.

Exercise and diet interventions in the treatment of diabetes are interrelated. However, intensive physical activity can cause various injuries, and also an over-restricted diet may lead to some nutrient deficiencies or impaired blood sugar regulation. The individuality of diet and exercise programs makes diabetes treatment more effective (40). In a study, prediabetic and T2DM patients applied a moderate-carbohydrate diet and a very low-carbohydrate diet. People who were on a very low-carb diet showed greater weight loss and more decrease in HbA1c levels and the dose of medication. Also, it was concluded that the effect of a very low-carbohydrate diet may be greater when prepared, considering the individual characteristics of the subjects (41). In this study, two different diabetic diets (personalized LC, MUFA, and HCC) and pilates exercise programs were applied. Following the measurements of the biochemical parameters, it was observed that the four interventions did not have a significant superiority in terms of final values of FBG, insulin, HbA1c, cholesterol, and HDL. Regarding LDL, the final values of the group treated with HCC were significantly higher than the group treated with LC, MUFA + PL, and the final values of the group treated with LC, MUFA were higher than the group treated with LC, MUFA + PL. The final TG values of the HCC-treated group were found significantly lower than those of the LC, MUFA-treated group. This was consistent with the studies indicating the additional benefits of the combined low-carb diets and exercise to improve glycemic control (32). In this study, the positive effects of exercise in diabetic patients on both anthropometric measurements and biochemical parameters were revealed.

It has emphasized that pilates is a reliable and effective exercise type for patients with diabetes and may be effective even in the treatment of diabetes (16). In a study by Yucel and Uysal (17), diabetics were recommended mat pilates exercises 3 times a week for 12 weeks. As a result, the decrease in FBG and HbA1c levels of diabetic patients doing pilates exercise was found significant compared with diabetic patients without exercise (17). In another study, pilates was considered for diabetics 3 times a week for 12 weeks and biochemical parameters of the pilates group and non-pilates group were compared. According to the obtained results, the decrease in fasting and postprandial glucose and HbA1c levels were found to be significant in the pilates group (26). The ADA 2019 guideline indicates the positive effect of the Mediterranean style diet (high in olive oil, omega-3, oilseed, fish, complex carbohydrates content) on weight loss/preservation in diabetic patients, as well as the treatment or prevention of diabetes (3). In this study, the decrease in FBGof diabetics who had LC, MUFA + PL was higher than the other groups, and also a decrease in HbA1c levels of those on LC, MUFA diet was found significant compared with cases treated with LC, MUFA + PL. This can be explained by the effectiveness of the Mediterranean style (high content of MUFA) nutrition in diabetes treatment.

In a study, in which the effect of lifestyle change on metabolic syndrome was investigated, saturated fat and polyunsaturated fat consumption of people in the intervention group decreased, whereas pulp consumption and physical activity level increased. Thus, the decrease in weight, waist circumference, and serum C-reactive protein of the intervention group was found significant. Lifestyle changes were found greatly effective in reducing metabolic syndrome and the incidence of obesity, diabetes, and hypertriglyceridemia (42). Oldroyd et al. (43) followed up cases with impaired glucose tolerance for 6 months by recommending healthy nutrition and physical activity. During this period, while the BMI of the subjects decreased significantly, the decrease in serum glucose and total cholesterol level was not significant (43). According to a meta-analysis compared the effects of diets with high GI and low GI, a low GI diet had positive effects on serum TG levels (44). In this study, the serum TG levels of those on LC, MUFA diet decreased significantly compared with those on the HCC diet. A statistically significant decrease was found in serum total cholesterol levels in cases who were on a diet rich in MUFA. This can be explained by the effectiveness of the Mediterranean style nutrition on blood lipids.

5.1. Limitations

This study was conducted only on female diabetic patients using pilates exercise. Nevertheless, further studies can be conducted on patients with different chronic diseases using other types of exercises.

5.2. Conclusions

In the treatment of diabetes, the patient should be evaluated with a multidisciplinary team. The combined diet and exercise is an important non-pharmacological intervention for treating diabetes and they are interrelated; therefore, they should be planned according to the patients' nutritional habits considering their lifestyle using expert personal health professionals. Personalized low-carb diets for diabetic enriched with omega 9 have a positive effect on both biochemical parameters and body composition along with regular exercise.

Footnotes

Authors' Contribution: Study concept and design: NB and HPD. Acquisition of data: SK analysis and interpretation of data: SK. Drafting of the manuscript: NB, SS, and AE. Critical revision of the manuscript for important intellectual content: SS, NB, and MGE. Statistical analysis: SK. Administrative, technical, and material support: S.S, MGE, and DG. Study supervision: NB.

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Ethical Approval: The Ethical Review Committee of Istanbul Gelisim University approved the study (approval code: 2017-13/2017-12-14).

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Table 2. Biochemical Results by Groups[a]

Variable	Measurement	Group	Values	Minimum	Maximum
FBG, mg/dL	Pre	LC, MUFA	116.56 ± 38.75	90.00	290.00
		LC, MUFA + PL	111.90 ± 26.25	92.00	233.00
		HCC	127.31 ± 36.59	90.00	196.00
		HCC + PL	134.26 ± 36.49	96.00	195.00
		Total	122.50 ± 35.53	90.00	290.00
	Post	LC, MUFA	110.76 ± 20.68	90.00	176.00
		LC, MUFA + PL	101.03 ± 9.65	90.00	135.00
		HCC	115.70 ± 22.62	90.00	174.00
		HCC + PL	111.10 ± 16.98	97.00	155.00
		Total	109.65 ± 18.72	90.00	176.00
Insulin, μU/mL	Pre	LC, MUFA	21.39 ± 15.39	9.50	82.20
		LC, MUFA + PL	26.30 ± 18.80	4.00	83.60
		HCC	21.26 ± 13.26	6.90	69.90
		HCC + PL	25.28 ± 17.06	6.50	83.60
		Total	23.56 ± 16.21	4.00	83.60
	Post	LC, MUFA	13.01 ± 6.74	7.40	35.20
		LC, MUFA + PL	12.81 ± 12.65	4.30	51.20
		HCC	15.40 ±	6.90	59.40
		HCC + PL	13.79 ± 10.87	5.06	51.20
		Total	13.75 ± 10.35	4.30	59.40
HbA1c, %	Pre	LC, MUFA	6.23 ± 1.25	5.10	11.80
		LC, MUFA + PL	5.86 ± 0.79	5.04	9.10
		HCC	6.28 ± 1.28	4.90	9.60
		HCC + PL	6.09 ± 0.99	5.00	9.90
		Total	6.12 ± 1.10	4.90	11.80
	Post	LC, MUFA	5.99 ± 1.26	4.80	11.50
		LC, MUFA + PL	5.16 ± 0.55	4.10	6.79
		HCC	5.74 ± 0.98	4.70	8.20
		HCC + PL	5.40 ± 0.84	4.30	8.50
		Total	5.57 ± 0.98	4.10	11.50
Total-Chol, mg/dL	Pre	LC, MUFA	205.60 ± 37.50	128.00	290.00
		LC, MUFA + PL	198.71 ± 37.15	124.00	276.00
		HCC	206.94 ± 38.85	131.00	300.00
		HCC + PL	197.21 ± 40.40	128.00	292.00
		Total	202.11 ± 38.24	124.00	300.00
	Post	LC, MUFA	189.46 ± 28.94	120.00	232.00
		LC, MUFA + PL	161.16 ± 32.26	102.00	250.00
		HCC	183.50 ± 34.71	122.00	267.00
		HCC + PL	152.90 ± 32.65	101.00	223.00

		Total	171.75 ± 35.25	101.00	267.00
HDL, mg/dL	Pre	LC, MUFA	44.08 ± 8.04	29.00	64.00
		LC, MUFA + PL	41.44 ± 6.17	34.00	64.00
		HCC	46.24 ± 9.03	35.50	79.00
		HCC + PL	43.12 ± 5.35	33.90	54.00
		Total	43.72 ± 7.41	29.00	79.00
	Post	LC, MUFA	44.20 ± 7.80	29.00	60.00
		LC, MUFA + PL	43.60 ± 6.03	35.00	66.00
		HCC	45.00 ± 10.07	27.00	79.00
		HCC + PL	45.26 ± 4.86	37.00	55.00
		Total	44.51 ± 7.39	27.00	79.00
LDL, mg/dL	Pre	LC, MUFA	146.35 ± 37.20	99.40	225.00
		LC, MUFA + PL	132.36 ± 29.19	95.00	216.00
		HCC	150.71 ± 31.55	108.00	213.00
		HCC + PL	151.75 ± 37.54	103.00	240.10
		Total	145.29 ± 34.51	95.00	240.10
	Post	LC, MUFA	136.23 ± 30.66	98.00	200.00
		LC, MUFA + PL	107.06 ± 15.28	92.00	160.00
		HCC	127.20 ± 20.36	101.00	167.00
		HCC + PL	121.43 ± 19.30	98.00	170.00
		Total	122.98 ± 24.31	92.00	200.00
TG, mg/dL	Pre	LC, MUFA	207.40 ± 94.70	58.00	560.00
		LC, MUFA + PL	188.37 ± 102.53	115.00	688.00
		HCC	162.55 ± 45.20	106.00	302.00
		HCC + PL	176.26 ± 58.37	106.00	365.00
		Total	183.65 ± 79.68	58.00	688.00
	Post	LC, MUFA	161.44 ± 46.42	72.00	260.00
		LC, MUFA + PL	128.86 ± 60.66	83.00	420.00
		HCC	117.86 ± 25.78	72.00	184.00
		HCC + PL	132.85 ± 41.56	76.00	228.00
		Total	135.25 ± 47.60	72.00	420.00

[a]Values are expressed as mean ± SD.

Table 6. Post-Hoc Comparisons for Blood Values[a]

Variable	Values	t	P Value (Bonferroni Test)
FBG, mg/dL			
HCC			
HCC + PL	-1.173 ± 6.654	-0.176	1.000
LC, MUFA	7.843 ± 6.654	1.179	1.000
LC, MUFA + PL	15.038 ± 6.654	2.260	0.154
HCC + PL			
LC, MUFA	9.017 ± 6.654	1.355	1.000
LC, MUFA + PL	16.212 ± 6.654	2.436	0.098
LC, MUFA			
LC, MUFA + PL	7.195 ± 6.654	1.081	1.000
Insulin, μU/mL			
HCC			
HCC + PL	-1.208 ± 3.367	-0.359	1.000
LC, MUFA	1.131 ± 3.367	0.336	1.000
LC, MUFA + PL	-1.226 ± 3.367	-0.364	1.000
HCC + PL			
LC, MUFA	2.339 ± 3.367	0.695	1.000
LC, MUFA + PL	-0.018 ± 3.367	-0.005	1.000
LC, MUFA			
LC, MUFA + PL	-2.357 ± 3.367	-0.700	1.000
HbA1c, %			
HCC			
HCC + PL	0.266 ± 0.258	1.032	1.000
LC, MUFA	-0.097 ± 0.258	-0.376	1.000
LC, MUFA + PL	0.501 ± 0.258	1.939	0.329
HCC + PL			
LC, MUFA	-0.363 ± 0.258	-1.408	0.971
LC, MUFA + PL	0.234 ± 0.258	0.908	1.000
LC, MUFA			
LC, MUFA + PL	0.598 ± 0.258	2.316	0.134
KOL, mg/dL			
HCC			
HCC + PL	20.167 ± 8.443	2.388	0.111
LC, MUFA	-2.310 ± 8.443	-0.274	1.000
LC, MUFA + PL	15.283 ± 8.443	1.810	0.437
HCC + PL			
LC, MUFA	-22.477 ± 8.443	-2.662	0.053
LC, MUFA + PL	-4.883 ± 8.443	-0.578	1.000
LC, MUFA			
LC, MUFA + PL	17.593 ± 8.443	2.084	0.236
HDL, mg/dL			
HCC			
HCC + PL	1.425 ± 1.870	0.762	1.000
LC, MUFA	1.477 ± 1.870	0.790	1.000
LC, MUFA + PL	3.100 ± 1.870	1.658	0.600
HCC + PL			
LC, MUFA	0.052 ± 1.870	0.028	1.000
LC, MUFA + PL	1.675 ± 1.870	0.896	1.000
LC, MUFA			
LC, MUFA + PL	1.623 ± 1.870	0.868	1.000
LDL, mg/dL			
HCC			
HCC + PL	2.363 ± 6.803	0.347	1.000

LC, MUFA	-2.337 ± 6.803	-0.343	1.000
LC, MUFA + PL	19.239 ± 6.803	2.828	0.033
HCC + PL			
LC, MUFA	-4.700 ± 6.803	-0.691	1.000
LC, MUFA + PL	16.876 ± 6.803	2.481	0.087
LC, MUFA			
LC, MUFA + PL	21.576 ± 6.803	3.172	0.012
TG, mg/dL			
HCC			
HCC + PL	-14.348 ± 15.248	-0.941	1.000
LC, MUFA	-44.215 ± 15.248	-2.900	0.027
LC, MUFA + PL	-18.408 ± 15.248	-1.207	1.000
HCC + PL			
LC, MUFA	-29.867 ± 15.248	-1.959	0.315
LC, MUFA + PL	-4.060 ± 15.248	-0.266	1.000
LC, MUFA			
LC, MUFA + PL	25.807 ± 15.248	1.692	0.559

[a]Values are expressed as mean ± SE.