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Original Research

Effects of Circuit Exercise Program on Cognitive Function, Functional Exercise Capacity, Mobility, Depression, and Quality of Life in Women with Gestational Diabetes

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Abstract

Objectives: The purpose of this study was to investigate the effects of circuit exercise programs applied in addition to diet therapy on cognitive function, functional exercise capacity, mobility, depression, and QoL in women with GD.
Materials and Methods: 43 women with GDM aged 18-35 years old were included and 43 were analyzed. A parallel, single-blind trial with participants allocated (1:1) to one of two groups the Exercise Group and the Diet Group. Personalized diet programs were received by all participants. In the Diet Group, only a diet program was performed. In the Exercise Group, a circuit exercise program was applied to 40-minute sessions, 3 days a week over 6 weeks in addition to the diet program. Participants were assessed at baseline, after 6 weeks for general cognitive function, attention, selective attention, functional exercise capacity, mobility, depression, and quality of life.
Results: Significant differences were found in terms of MoCA, Stroop ve SF-36 Physical Functioning in both groups (p<0.05). In Time*Group evaluations, there was a significant difference in the WMS Backward Digit Span in favor of the Diet Group, and in TUG in favor of the Exercise Group (p<0.05).
Conclusion: In conclusion, personalized diet programs may enhance cognitive functions, and circuit exercise programs in addition to the personalized diet program may enhance mobility and cognitive functions in women with GD.

Keywords: *cognition, diet, exercise, gestational diabetes*

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Introduction

Gestational diabetes mellitus (GDM), defined as carbohydrate intolerance diagnosed in the second or first trimester of pregnancy, can cause maternal hyperglycemia, increased glucose transport in the placenta, fetal hyperinsulinemia, and accelerated growth in the fetus. Although maternal insulin resistance improves immediately after the baby is born, symptoms and signs associated with hyperglycemia such as polyuria, polydipsia, blurred vision, and fatigue can be observed when GDM is not detected or is inadequately controlled (Metzger, 2007).

The underpinning of GDM treatment consists of lifestyle modifications, also including medical nutritional therapy, exercise, weight management, and glucose monitoring. Depending on the diagnostic criteria of women, 80-90% of GDM can be managed with lifestyle interventions alone (Dickens & Thomas, 2019). The American Diabetes Association (ADA) emphasizes that GDM must be managed with diet and exercise first (Colberg et al., 2016). Furthermore, drug therapy, especially insulin, should only be used when lifestyle modifications are insufficient. According to the ADA, individuals with GDM should first receive nutritional counseling from a dietitian. The targets of nutritional counseling seem to be to prevent excessive maternal weight gain, promote healthy fetal growth, avoid ketosis, and provide the mother and fetus with both the appropriate amount of calories (Vasile et al., 2021). Exercise is regarded as adjunctive therapy in the treatment of type II DM (diabetes mellitus) in non-pregnant individuals due to its capacity to improve insulin sensitivity and insulin-stimulated muscle glucose uptake, and exercise is an effective intervention in preventing and managing GDM (Cremona et al., 2018). A structured exercise program that included a combination of aerobic and strength exercises had a beneficial effect on pregnant women's postprandial glucose levels, according to the outcomes of a randomized clinical trial (Taylor, 2018). According to an international guideline, 30 minutes of moderate-intensity aerobic exercise should be performed at least five days a week by women with GDM, in addition to diet therapy (American College of Obstetricians and Gynecologists [ACOG], 2018). In addition, studies show that exercise considerably improves postprandial glycemic control, lowers fasting blood sugar in women with GDM, and may even prolong the need to use insulin (Harrison el al., 2016; Colberg el al., 2013).

Although studies on individuals with GDM demonstrate the benefits of individual diet therapy and structured exercise therapy separately, to our knowledge there has been no study comparing their effectiveness in comparison to each other. The purpose of this study was to investigate the effects of circuit exercise programs applied in addition to diet therapy on cognitive function, functional exercise capacity, mobility, depression, and quality of life (QOL)

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in women with GD.

Materials and Methods

Study Design

This study was a parallel, double-blind (participants and raters) randomized controlled trial in which participants were allocated to one of two groups (1:1). The protocol of the study was registered at ClinicalTrials.gov (NCT05096078). This trial was approved by the Non-interventional Ethics Committee at Istanbul Medipol University, Turkey (File number: 10840098-772.02-E.5895) and was conducted by the principles of the Declaration of Helsinki. All participants provided written informed consent.

Study Population

The study was conducted with participants who applied to the obstetrics service of Special Tema Hospital in Istanbul and had a glucose load test between the 24th and 32nd weeks of pregnancy. The study was conducted between September 2020 and May 2022. The participants who were diagnosed with GDM, between 18-35 years old, at 24-32 weeks of pregnancy, and with an inactive level of physical activity were included in the study. The exclusion criteria were defined as diagnosed with diabetes before pregnancy, having multiple pregnancies (>2), having intrauterine growth restriction, preeclampsia, having a high risk of preterm labor, and being on strict bed rest being treated with insulin or oral hypoglycemic agents during pregnancy, having other significant severe or weak having controlled medical conditions (thyroid disease, cardio-respiratory disorders, etc.), taking medications that affect cognitive function, including corticosteroids, antidepressants, or anti-epileptic drugs.

The sample size was determined using the "G*power sample size calculator" and was calculated as 40 subjects using “ANOVA: Repeated measures, within-between interaction” design for two groups, with a power of 95% (α=0.05, β=0.95) and an effect size of 0.30.

52 participants were screened, 4 of them were diagnosed with diabetes before pregnancy, and 3 of them were taking insulin therapy during pregnancy. 45 participants who met the inclusion criteria were included in the study. 2 of them did not want to continue the study and the study was completed with 43 participants. The flow diagram of the study was shown in Figure 1.

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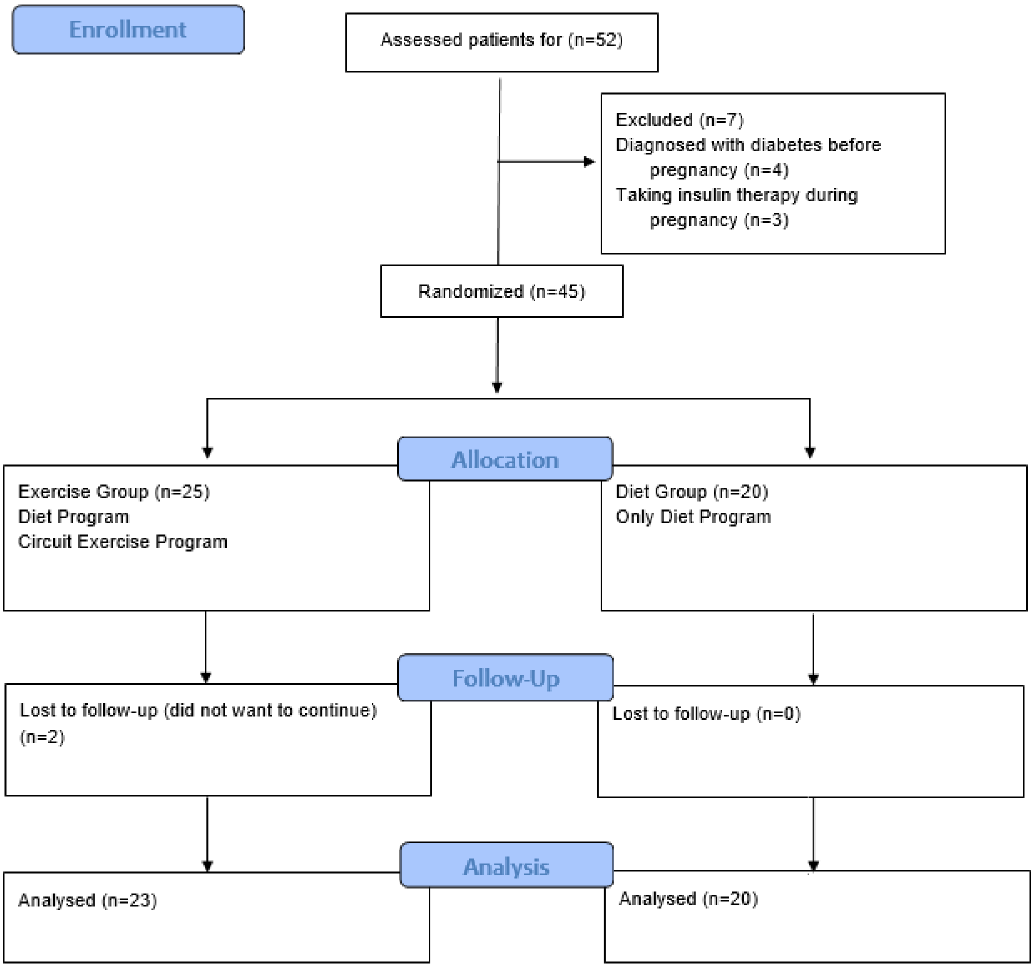

Figure 1. Flowchart for the participant allocation

Experimental Design

Forty-three participants were included in the study and were randomly divided into two groups using block randomization in Microsoft Excel 'RAND(WS)' function as the Diet Group (n=20) and the Exercise Group (n=23). Diet programs were applied over 6 weeks in both groups. The circuit exercise program was applied to 40-minute sessions, 3 days a week over 6 weeks in addition to the diet program in the Exercise Group. Participants were evaluated at the beginning and the end of the study.

Diet Protocol: A personalized diet program was prescribed to the participants by the dietitian over 6 weeks, which was arranged according to the physiological data of the individuals. The number of meals was determined as 3 main meals and 3-4 snacks. The dietitian calculated the energy amount of the diet according to the individual's age, pre-pregnancy weight, physical activity, and week of pregnancy. It was planned that 40-45% of the daily energy would consist

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of carbohydrates, 15-20% of proteins, and 20-35% of fats. Foods that raise blood sugar rapidly, such as sugar, honey, molasses, fruit juice, and chocolate, were restricted.

Circuit Exercise Protocol: The circuit exercise program which includes warm-up (5 minutes), circuit exercise (30 minutes), and cool-down (5 minutes) periods was applied to 40-minute sessions, 3 days a week over 6 weeks in addition to the diet program in the Exercise Group. Each exercise was initially performed under the supervision of a physiotherapist as 1 set of 10 repetitions, and the progression of the exercises was increased in direct proportion to the development of the individuals. The circuit exercise program was shown in Table 1.

Table 1: Circuit Exercise Program

Warm-up period (5 min)	**Stretching exercises**
	Flexibility exercises
Circuit exercise period (30 min)	Scapula Retraction Sumo Squat Sit to Stand Chest Press Cat-Camel Exercise Lower Extremity Extension in Crawling Position Contralateral Lower And Upper Extremity Extension İn The Crawling Position Sit-Stand Exercise in Knee-bend Position Hip Abduction And Adduction in Side Lying Clamshells Exercise
Cool-down period (5 min)	Deep breathing
	Diaphragmatic breathing

Outcome Measurements

Participants were evaluated for general cognitive functions with Montreal Cognitive Assessment Scale (MoCA), for attention with WMS Digit Span Test, for processing speed and selective attention with Stroop Test, for functional exercise capacity with the 6-Min Walk Test (6 MWT), for mobility with Timed-up and Go Test (TUG), for depression with Beck Depression Inventory (BDI), and QOL with Short Form 36 (SF-36) at the beginning and the end of the study.

Demographic Information Form: It was prepared to record the sociodemographic characteristics of participants.

MoCA: It is a scale that requires memory, and visuospatial skills and evaluates executive functions, attention, concentration, abstract thinking, orientation functions, and language-related functions. MoCA takes about 10 minutes to apply. The highest total score that can be

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obtained from the test is 30. A score of 26 points or more is considered normal. The Turkish validity and reliability study of the test was performed. (Selekler & Sait, 2010).

WMS Digit Span Test: The Digit Span Test is a subtest of both the Wechsler Adult Intelligence Scale (WAIS) and the Wechsler Memory Scales (WMS). Digit Span has been comprised of two parts on the WMS: Digit Span Forward and Digit Span Backward. In the forward digit span, which measures short- term memory and attention, the patient is asked to repeat the numbers told to him in the same order, and in the backward digit span, the patient is asked to repeat the numbers from the end to the beginning. The test is terminated when the patient makes two consecutive errors in the same numerical space (Kent, 2013).

Stroop Test: It consists of a total of 60 red, blue, and green colored boxes and 60 randomly ordered red, green, and blue words written in mismatched colors. In the first step, the patient is asked to say the colors of the boxes as quickly as possible. In the second stage, words written in incompatible colors are asked to be read. In the third stage, they are asked not to read the words written in incompatible colors and to say only the colors of the words. The time between the second and third stages measures the sensitivity to interference, the error number measures the inhibition control (Rozenblatt, 2011).

6-Min Walk Test: It is a widely used test to evaluate functional capacity. Its standard protocol is implemented in a continuous 30-meter corridor or open space. Marks are placed every 3 meters. The test is repeated three times and the maximum walking distance is taken into account (American Thoracic Society [ATS], 2002).

TUG: It is used to examine the functional mobility, balance, and fall risk of individuals. The person is asked to get up from the seat without holding on to the arms of the chair, to return after walking three meters without touching anything, and to return to the sitting position by walking towards the chair (Tander et al., 2016).

BDI: It was developed to measure the severity of depression, monitor the changes with treatment, and define the disease. The Turkish validity and reliability study was performed by. If the total value is 9 or less, it is considered "no depression", 10-16 is "mild", 17- 23 is "moderate", and 24 and above is considered severe "depression" (Tekindal & Tekindal, 2021).

SF-36: It is a total of 36 items that can be filled in by the patient. It examines health in 8 subscales (physical function, physical role difficulty, emotional role difficulty, energy, mental health, social function, pain, and general health perception). Subscales evaluate health between 0 and 100, with 0 indicating poor health and 100 indicating good health. Turkish validity and reliability study was performed by Koçyiğit et al. (Koçyiğit & Fişek, 1999).

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Statistical Analysis

IBM SPSS (Statistical Package for Social Science) version 25.0 was used for statistical analysis. Mean, standard deviation, and percentage values were presented in the descriptive statistics of the data. The nominal data of the independent variables were evaluated with the Chi-Square Test, and the numerical data were evaluated with the Independent Sample-T Test. Time-dependent differences within groups were analyzed with Two-Way Repeated Measure ANOVA and Time*Group interactions between groups were analyzed with MANOVA. Bonferroni correction was used for Post-Hoc tests. The significance value was accepted as $p<0.05$.

Results

Demographic Data

The average age of the participants was 30.61 ± 3.60 year in the Exercise Group and 28.95 ± 4.34 in the Diet Group. There were statistically significant differences in terms of the number of pregnancies, fasting glucose, 2nd-hour postprandial glucose, sugar test, and education between groups ($p>0.05$). The demographic data of the participants were shown in Table 2.

Within Group Differences

Within-group differences in the Exercise Group was shown in Table 3. There were statistically significant improvements in terms of MoCA, WMS Forward Digit Span, Stroop Test, 6MWT, TUG, and SF-36 physical function ($p<0.05$).

Within-group differences in the Diet Group was shown in Table 4. There were statistically significant improvements in terms of MoCA, WMS Backward Digit Span, Stroop Test, SF-36- physical function, and SF-36-physical role difficulty ($p<0.05$).

Between Group Differences & Time*Group Interaction

Between group differences and Time*Group interactions were shown in Table 5. There were statistically significant improvements in terms of WMS Backward Digit Span in favor of the Diet Group, and in terms of TUG in favor of the Exercise Group ($p<0.05$).

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Table 2 : Demographic data

		Groups			
		Exercise Group (n=23)	**Diet Group (n=20)**	**t / X^2**	**p**
Age (Mean ± SD) (year)		30.61 ± 3.60	28.95 ± 4.34	1.368	0.179
Height (Mean ± SD) (cm)		163.87 ± 4.78	165.15 ± 4.15	- 0.929	0.358
Gestational week (Mean ± SD)		28.04 ± 2.24	29.30 ± 2.36	- 1.786	0.082
Pregnancy start weight (Mean ± SD) (kg)		68.91 ± 11.75	68.75 ± 14.61	0.041	0.968
Weight before treatment (Mean ± SD) (kg)		76.31 ± 11.60	76.00 ± 13.84	0.081	0.936
Weight after treatment (Mean ± SD) (kg)		78.42 ± 11.54	78.44 ± 14.48	- 0.007	0.995
Number of pregnancies (Mean ± SD)		1.21 ± 0.42	1.60 ± 0.75	-2.089	**0.043***
Fasting sugar (Mean ± SD)		67.83 ± 42.68	36.65 ± 48.97	2.231	**0.031***
1-hour PPG measurement (Mean ± SD)		165.30 ± 26.23	159.35 ± 27.17	0.730	0.469
2-hour PPG measurement (Mean ± SD)		64.73 ± 79.95	16.25 ± 50.13	2.340	**0.024***
OGTT (n / %)	50 gr OGTT	13 / 56.5	18 / 90	5.959	**0.015***
	75 gr OGTT	10 / 43.5	2 / 10		
Education (n / %)	High school	3/13	7/35	0.767	**0.000***
	University	20/87	13/65		
Working status (n / %)	Worker	15 / 65.2	11 / 55	0.467	0.494
	Housewife	8 / 34.8	9 / 45		

(SD: Standard deviation, PPG: Postprandial Glucose, OGTT: Oral Glucose Tolerance Test, n: number of people
*p<0.05)

Table 3. Within Group differences in Exercise Group

Exercise Group (n= 23)		Pre-Treatment	Post-Treatment	Mean Difference	Confidence Interval (Upper Limit / Lower Limit)
Parametre	**Ölçek**	**Mean ± SD**	**Mean ± SD**		
General Cognitive Function	**MoCA**	27.15±2.03	27.95±1.90	0.800	0.381/1.219
Attention	**Forward WMS Digit Span Test**	7.00±0.97	7.35±0.67	0.350	0.121/0.579
	Backward WMS Digit Span Test	4.45±1.05	4.60±1.04	0.150	-0.021/0.321
Selective Attention	**Stroop Test**	33.50±10.03	29.25±9.17	-4.250	-8.232/-0.268
Functional Capacity	**6 MWT**	320.35±58.59	291.10±67.60	-29.250	-41.286/-17.214
Functional Mobility	**TUG**	9.30±1.86	10.95±2.35	1.650	1.140/2.160
Depression	**BDI**	10.00±4.55	9.84±4.40	-0.158	-1.251/0.935
	SF-36 Physical Functioning	68.00±18.02	55.50±18.63	-12.500	-22.238/-2.762
	SF-36 Role-Physical	45.00±37.69	42.50±37.25	-2.500	-15.033/10.033

Quality of Life	**SF-36 Role-Emotional**	48.33±38.19	36.66±37.30	-11.666	-25.318/1.985
	SF-36 Vitality	58.75±19.18	57.50±18.02	-1.250	-9.700/7.200
	SF-36 Mental Health	67.40±17.13	71.80±15.81	4.400	-0.678/9.478
	SF-36 Social Functioning	74.37±24.15	76.87±19.98	2.500	-6.721/11.721
	SF-36 Bodily Pain	57.37±24.47	47.87±22.35	-9.500	-19.768/0.768
	SF-36 General Health	66.50±12.68	67.00±13.41	0.500	-1.494/2.494

(SS: Standard deviation, F: Frequency, n: number of people , MoCA: Montreal Cognitive Assessment, WMS: The Wechsler Mer
Test, TUG: Timed Up and Go Test, BDI: Beck Depression Inventory, SF-36: 36-Item Short Form Survey *p<0.05)

Table 4. Within Group differences in Diet Group

Diet Group (n= 20)		Pre- Treatment	Post-Treatment	Mean Difference	Confidence Interval (Upper Limit / Lower Limit)	F
Parametre	**Ölçek**	**Ort ± SS**	**Ort ± SS**			
General Cognitive Function	**MoCA**	27.13±1.79	28.52±1.23	1.391	0.717/2.066	18.315
Attention	**Forward WMS Digit Span Test**	7.08±1.20	7.30±0.82	0.217	-0.101/0.536	2.007
	Backward WMS Digit Span Test	4.60±1.03	5.34±1.07	0.739	0.414/1.064	22.231
Selective Attention	**Stroop Test**	33.39±10.81	25.30±9.05	-8.087	-12.984/-3.189	11.727
Functional Capacity	**6 MWT**	325.13±66.46	314.91±73.33	-10.217	-22.815/2.381	2.829
Functional Mobility	**TUG**	9.30±1.94	9.30 ± 1.66	0.000	-0.568/0.568	0.000
Depression	**BDI**	6.86±4.80	6.21 ± 5.29	-0.652	-1.756/0.451	1.503
	SF-36 Physical Functioning	72.17±12.77	64.34±13.75	-7.826	-13.759/-1.893	7.483
	SF-36 Role-Physical	64.13±32.70	43.47±36.32	-20.652	-36.166/-5.138	7.622

Quality of Life	**SF-36 Role-Emotional**	71.01±28.96	59.42±42.58	-11.596	-27.030/3.838	2.428
	SF-36 Vitality	56.52±22.22	57.60±21.78	1.087	-5.872/8.046	0.105
	SF-36 Mental Health	71.30±19.13	72.52±19.90	1.217	-4.807/7.242	0.176
	SF-36 Social Functioning	7.19±24.83	69.02±24.67	-2.174	-11.487/7.139	0.234
	SF-36 Bodily Pain	60.76±21.25	60.76±22.11	0.000	-5.912/5.912	0.000
	SF-36 General Health	67.50±14.61	69.09±12.59	1.591	-2.592/5.774	0.626

(SS: Standard deviation, F: Frequency, n: number of people , MoCA: Montreal Cognitive Assessment, WMS: The Wechsler Me
Test, TUG: Timed Up and Go Test, BDI: Beck Depression Inventory, SF-36: 36-Item Short Form Survey *p<0.05)

Table 5. Between Group Differences & Time*Group Interaction

Parameter	Measurement	Pre-Treatment			Post-Treatment			
		Exercise Group (n= 23)	Diet Group (n= 20)	p	Exercise Group (n= 23)	Diet Group (n= 20)	p	Mean Difference
		Ort ± SS	Ort ± SS		Ort ± SS	Ort ± SS		
General Cognitive Function	**MoCA**	27.15±2.03	27.13±1.79	0.973	27.95±1.90	28.52±1.23	0.244	0.276
Attention	**Forward WMS Digit Span Test**	7.00±0.97	7.08±1.20	0.798	7.35±0.67	7.30±0.82	0.844	0.021
	Backward WMS Digit Span Test	4.45±1.05	4.60±1.03	0.621	4.60±1.04	5.34±1.07	**0.026***	0.453
Selective Attention	**Stroop Test**	33.50±10.03	33.39±10.81	0.973	29.25±9.17	25.30±9.05	0.164	-2.027
Functional Capacity	**6 MWT**	320.35±58.59	325.13±66.46	0.805	291.10±67.60	314.91±73.33	0.277	14.297
Functional Mobility	**TUG**	9.30±1.86	9.30±1.94	0.994	10.95±2.35	9.30 ± 1.66	**0.011***	-0.821
Depression	**BDI**	10.00±4.55	6.86±4.80	**0.043***	9.84±4.40	6.21 ± 5.29	**0.022***	-3.378

Quality of Life	**SF-36 Physical Functioning**	68.00±18.02	72.17±12.77	0.381	55.50±18.63	64.34±13.75	0.081	6.511
	SF-36 Role-Physical	45.00±37.69	64.13±32.70	0.082	42.50±37.25	43.47±36.32	0.931	10.054
	SF-36 Role-Emotional	48.33±38.19	71.01±28.96	**0.033***	36.66±37.30	59.42±42.58	0.072	22.719
	SF-36 Vitality	58.75±19.18	56.52±22.22	0.729	57.50±18.02	57.60±21.78	0.986	-1.060
	SF-36 Mental Health	67.40±17.13	71.30±19.13	0.488	71.80±15.81	72.52±19.90	0.897	2.313
	SF-36 Social Functioning	74.37±24.15	7.19±24.83	0.674	76.87±19.98	69.02±24.67	0.263	-5.516
	SF-36 Bodily Pain	57.37±24.47	60.76±21.25	0.630	47.87±22.35	60.76±22.11	0.065	8.136
	SF-36 General Health	66.50±12.68	67.50±14.61	0.714	67.00±13.41	69.09±12.59	0.605	1.545

(SS: Standard deviation, F: Frequency, n: number of people , MoCA: Montreal Cognitive Assessment, WMS: The Wechsler Mem
TUG: Timed Up and Go Test, BDI: Beck Depression Inventory, SF-36: 36-Item Short Form Survey *p<0.05)

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Discussion

In the present study, we investigated the effects of circuit exercise programs in addition to diet therapy on cognitive function, functional exercise capacity, mobility, depression, and quality of life in women with GDM. It was observed that personalized diet programs may enhance cognitive functions, and circuit exercise programs in addition to the personalized diet program may enhance mobility and cognitive functions in women with GDM.

Preeclampsia, high blood pressure, and potential type II DM seem to be just some of the many well-known complications of GDM, but its effect on cognitive function has received less attention. In a study, the MoCA scale was used to evaluate the cognitive abilities of people with GDM in healthy pregnant women (Sana et al., 2021). It was shown that individuals who had GDM had significantly lower scores in executive function, naming, delayed recall, and total score. Protein glycation and the formation of advanced glycation end products are directly increased by hyperglycemia. Poor glycemic control and increased stiffness of the capillaries in the vascular bed of several organs, including the lungs, have both been related to this condition. Diabetes patients may have decreased exercise capacity because of impaired glucose metabolism. According to a study, people with type II DM showed 6 MWT scores that were considerably lower than among adults without the condition (Adeniyi el al., 2010). Considering that pregnancy significantly alters a woman's neuroendocrine and psychosocial status, it may increase the susceptibility to depression. Moreover, the risk of depression may increase when a woman has diabetes when she is pregnant. According to Kozhimannil et al. (2009), having diabetes increases the risk of developing depression during the prenatal period. Another study, however, reported no noticeable difference in depression symptoms between pregnant women with and without gestational diabetes (Keskin et al., 2015). Although the physiological, psychological, and sociological aspects of women change rapidly during pregnancy, little is known about the quality of life for pregnant women (Sahrakorpi et al., 2017). Studies evaluating QoL show that the diagnosis of GDM does not affect women's health status or quality of life during pregnancy or postpartum (Kim et al.,2005; Sahrakorpi et al., 2017). However, Dalfra et al. (2012) showed in their study that women with GDM scored lower in the third-trimester general health perception sub-parameter compared to women without GDM.

Diet treatment is recommended for pregnant women with GDM to improve glycemic control, prevent ketosis, achieve nutritional needs, and assist in the development of the unborn baby (Horsch et al., 2018). It is emphasized that more studies are required to evaluate the outcomes of various dietary interventions to be administered to women with GDM. According to a pilot study, a high-complex carbohydrate/low-fat diet decreased glycemic load and insulin

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resistance in women with GDM (Hernandez et al., 2016). The assumption that modifiable components of diet and lifestyle are related to cognitive function is supported by epidemiologic studies (Caracciolo et al., 2014; Dong et al., 2016). The risk of cognitive impairment is reduced by consuming individual diet categories (such as fish and vegetables) and nutrients (such as vitamins C, E, B6, and B12, folate, potassium, calcium, magnesium, and unsaturated fatty acids). According to Dong et al. (2016), consuming fruits and vegetables has a strong correlation with attention and concentration. Furthermore, it has been observed that consuming legumes may improve overall cognition and that there is no conclusive evidence connecting consuming whole grains, fish, red meat, eggs, coffee, tea, or milk to overall cognitive function. In our study, the dietitian conducted one-on-one interviews with individuals in both groups. After these interviews, the dietitian prepared personalized diet programs taking into account each person's physiological requirements. Personalized diet programs such as 3 main meals and 3-4 snacks, taking 40-45% of daily energy from carbohydrates, 15-20% from proteins, and 20-35% from fats, were prescribed to all participants over 6 weeks.

Dietary interventions have the potential to be an effective and preventive strategy for cognitive impairment. One study has shown that dietary intervention, particularly the Mediterranean diet, has some benefits on cognitive function (Morris et al., 2015). Gluck et al. (2013) reported an association between impaired glucose regulation and decreased performance on the Stroop/Word Color task in a group of young and middle-aged adults. In a study, it was reported that GDM treatment (dietary advice, blood glucose monitoring, and insulin therapy as needed) reduced perinatal morbidity and improved the health-related quality of life of women (Crowther et al., 2005). There were significant improvements in terms of general cognition, attention, executive functions, and QoL. It may be argued that healthily modifying eating and drinking habits enhance the quality of life, notably cognition.

Exercise has a positive effect on glycemic control in pregnant women with GDM. Exercise has a positive effect on glycemic control in pregnant women with GDM. Brankston et al. (2004) showed that circuit-type resistance exercise training helped avoid insulin therapy in overweight women with gestational diabetes. It has been reported that intensive care such as diet counseling and exercise can improve the level of glycosylated HbA1c, reduce the frequency of birth weight in infants higher for gestational age, reduce weight gain during pregnancy, and lead to a lower depression rate even three months after birth, compared to standard care (Brown et al., 2017). In our study, in addition to personalized diet programs, a structured circuit exercise program was applied to the individuals in the exercise group under the supervision of a physiotherapist in 40-minute sessions, 3 days a week, over 6 weeks.

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Exercise can improve cognitive performance regardless of the cognitive task, individual characteristics, and training method by enhancing brain activation, cerebral blood flow, and perfusion (Guicciardi et al., 2020). According to a meta-analysis, healthy adults over the age of 50 who exercise for 45–60 minutes at a moderate intensity and as frequently as possible have improved general cognition, attention, executive functions, and working memory (Northey et al., 2018). In our study, we also utilized MoCA to evaluate general cognitive function. Both groups' MoCA test scores demonstrated significant improvements, despite the absence of any noticeable difference between the groups. These results suggest that diet therapy and exercise therapy in addition to diet therapy have similar effects on general cognitive function.

Executive functions are known to be impaired by chronic illnesses like DM. The association between executive functions and other types of diabetes (gestational diabetes and special type diabetes) has not been extensively studied, even though there are several studies on executive function in type I DM and type II DM patients. Wateri et al. (2006) reported that individuals with diabetes had worsened especially in executive function compared to non-diabetic individuals. According to a study investigating the relationship between Stroop Test scores and impaired glucose regulation, it was shown that even mild hyperglycemia in the non-diabetic range was associated with difficulty in selective attention in a sample of young adults (Gluck et al., 2013). In a study conducted with individuals with type II DM, it was reported that Stroop test scores improved in individuals who received 8 weeks of structured exercise therapy in addition to diet and drug therapy (Kour et al., 2015). In our study, we evaluated the processing speed and selective attention of the participants before and after the treatment using the Stroop Test, and although significant improvements were found in the Stroop Test results in both groups, no significant difference was found between the groups. This suggests that diet therapy alone may also have a positive effect on processing speed and selective attention in individuals with GDM. In this context, it was concluded that more studies are required to show how diet therapy affects processing speed and selective attention in individuals with GDM.

Psychomotor speed and attention/integration are reported to be considerably lower in women with GDM (Sahrakorpi et al., 2017). According to a meta-analytic review of randomized controlled trials, exercise interventions were related to improvements in processing speed and attention, and longer- duration exercise interventions seemed to have no greater impact on these outcomes than shorter-duration interventions (Smith et al., 2010). In our study, we evaluated attention using the WMS Digit Span Test and found that the exercise group considerably enhanced the WMS Forward Digit Span scores. From the research viewpoint,

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combining dietary recommendations with a structured circuit exercise program helps people improve overall basic attention.

Patients with type II DM have a deterioration in functional mobility due to neuropathic and vascular consequences. 6MWT and TUG are reliable measures of physical function in adults with type II DM, allowing physiotherapists to monitor changes in physical function with exercise prescription. In a randomized controlled study, it was observed that a 12-week resistance exercise program improved the TUG score in patients with knee osteoarthritis with type II DM (Chen et al., 2019). We discovered a substantial improvement in the exercise group's TUG scores, which evaluate functional mobility. Our findings are consistent with examples of scientific research on the effect of an exercise intervention on physical function. It could be suggested to begin a 40-minute exercise program, 3 days a week, for 6 weeks, to boost the functional capacity of people with GDM.

There is limited evidence in the literature that high physical activity levels during pregnancy are associated with reduced symptoms of depression during pregnancy. BDI was utilized in our study to evaluate all participant's levels of depression. Although BDI scores decreased in both groups in our study, it was not statistically significant. We assume that though the participants' blood glucose levels were not high enough to require insulin treatment, those who only experienced mild - to - moderate depression. That's regardless of the reality that both the diet and the exercise program used in addition to the diet had shown improvement through the end of the six-week.

Poor glycemic control, the presence of complications, and the requirement for insulin treatment harm the QoL for people with diabetes. According to the review by Sahrakorpi et al. (2019), diabetes- related self-management interventions may be able to enhance a person's decreased QoL (diet, exercise, self-monitoring, insulin control). After treatment, both groups' SF-36 Physical Function scores were considerably enhanced as compared to their pretreatment scores in our study. We concluded that only 6 weeks of individualized diet therapy resulted in improvement in SF-36 Physical Role Difficulty scores. We assume that this result is since blood glucose level was controlled with individualized diet therapy.

According to our study and the literature, we can see that diet and exercise therapy can enhance cognitive functions. Therefore, we consider that along with aerobic exercises in the exercise program will assist in enhancing cognitive functions. The efficacy of dietary or exercise treatments in the management and prevention of GDM has been thoroughly examined in the literature. Nevertheless, there has been a recent phenomenon of combining diet and

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exercise interventions (Allehdan et al., 2019). We suggest it would be beneficial to evaluate the effects of the circuit exercise program being used in addition to diet therapy for this reason.

Strengths of the study

While there are studies in the literature focusing on how exercise affects cognitive functions in people with type II DM, there are numerous investigations into how exercise affects cognitive functions in people with GDM. According to our knowledge, this study's strength is that it is the first in the literature to examine the impact of a circuit exercise program added to diet treatment on cognitive function, functional exercise capacity, mobility, depression, and QoL in pregnant women with GDM.

Limitations of the study

The limitation of this study is the decreased ability to detect the relationship between cognitive function, functional exercise capacity, mobility, depression, and QoL parameters with adiposity due to a limited BMI range. Additionally, participants were asked verbally about their physical activity levels and the answer was that they only spent time at home and were not active. Physical activity level was not assessed using a questionnaire.

Conclusion

In conclusion, personalized diet programs may enhance cognitive functions, and circuit exercise programs in addition to the personalized diet program may enhance mobility and cognitive functions in women with GD.

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Declaration of Competing Interest

There is no conflict of interest between any institution, organization or researchers within the scope of the study.

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