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ORIGINAL RESEARCH

Effects of Moderate-Intensity Aerobic Exercise on Blood Glucose Levels and Pregnancy Outcomes in Patients With Gestational Diabetes Mellitus: A Randomized Controlled Trial

Xie Yaping · Zhao Huifen · Zhao Meijing · Huang Huibin · Liu Chunhong · Huang Fengfeng · Wu Jingjing

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ABSTRACT

Introduction: To investigate the effects of structured moderate-intensity aerobic exercise on blood glucose, insulin, and pregnancy outcomes in patients with gestational diabetes mellitus (GDM).

Methods: One hundred one patients with GDM were randomly divided into a control group (50 cases) and an experimental group (51 cases) in a class 3 first-level general hospital. GDM patients in the control group received a personalized diabetes diet intervention, online education, and routine prenatal care. The experimental group added 6 weeks of moderate-intensity aerobic exercise in addition to the identical conditions given to the control group. The differences of fasting and 2-h postprandial blood glucose, insulin use, and adverse pregnancy outcomes were evaluated between the experimental and control group after intervention.

Results: Outcomes were available from 89 participants. Compared with before intervention, there were statistically significant differences in fasting blood glucose and 2-h blood glucose after three meals in both groups ($P < 0.05$). There were statistically significant differences in the average fasting blood glucose, the average 2-h postprandial blood glucose, the insulin dosage, and the utilization rate between the experimental and control group after the intervention ($P < 0.05$). Parameters in the experimental group were all lower than in the control group. Compared with the control group, the incidence of adverse pregnancy outcomes in the experimental group after intervention was not statistically significant ($P > 0.05$).

Conclusion: Moderate-intensity aerobic exercise can help improve blood glucose control and insulin use in patients with GDM. In the future, long-term follow-up can be conducted for maternal and neonatal infants to evaluate the

Z. Huifen (✉) · H. Fengfeng
Clinical Nursing Teaching and Research Department, Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian Province, China
e-mail: 624633497@qq.com

X. Yaping
Nursing Department, Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian Province, China

Z. Meijing · W. Jingjing
Gynaecology and Obstetrics Department, Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian province, China

H. Huibin
Endocrinology Department, Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian province, China

L. Chunhong
Outpatient Department, Second Affiliated Hospital of Fujian Medical University, Quanzhou, Fujian Province, China

impact of exercise intervention on the risk of type 2 diabetes.
Clinical Trial Registration: The trial was approved by the registration of the Chinese Clinical Trial Registry. Registration number: ChiCTR1900027929.

Keywords: Aerobic exercise; Gestational diabetes mellitus; Non-pharmacological intervention; Blood glucose control; Randomized controlled trial

Key Summary Points

Globally, the incidence of gestational diabetes mellitus (GDM) is increasing yearly, becoming a high-incidence metabolic disorder. GDM can affect normal pregnancy and delivery processes, leading to an increased risk of adverse pregnancy outcomes.

At present, most studies on aerobic exercise in patients with GDM focus on subjects exercising at home by themselves, while researchers inquired whether the exercise intervention was carried out as scheduled through telephone follow-up. Since researchers did not organize the exercise intervention on site, it may be difficult to control the exercise intensity, frequency, and quality of the exercise intervention.

In this study, structured moderate-intensity aerobic exercise intervention with supervision and planning was carried out. The results showed that this regimen had a positive effect on blood glucose control and insulin use in GDM patients. In addition, this is a safe, non-pharmacological intervention strategy for this population.

INTRODUCTION

Gestational diabetes mellitus (GDM) refers to any degree of abnormal glucose tolerance first detected during pregnancy [1]. GDM accounts for ~ 90–95% of all patients with hyperglycemia during pregnancy [2]. Globally, the prevalence of GDM is increasing yearly, becoming a high-incidence metabolic disorder. At present, the prevalence of GDM in different countries ranges from 2 to 32% [3], and the prevalence of GDM in developing countries has increased by > 30% in 20 years [4]. The prevalence of GDM in China is 17.5% [4]. This health crisis has caused a serious economic burden on public health care institutions.

GDM can affect the normal pregnancy and delivery process, leading to an increased risk of adverse pregnancy outcomes. In the mother, it can increase the risk of complications, including pregnancy hypertension, hyperhydramnios, preeclampsia, and other complications [5,6]. It may increase the risk of preterm delivery, macrosomia, hyperinsulinemia, and hypoglycemia for fetuses and newborns [7]. In addition, 60% of pregnant women with GDM will develop type 2 diabetes in 5–10 postpartum years [8]. This outcome can produce cross-generation effects, resulting in the probability of obesity, diabetes, and kidney disease in the offspring more than 2–8 times that of non-GDM pregnant women [9]. Therefore, it is crucial to improve the adverse effects caused by GDM.

Long-term lifestyle interventions are known to improve blood glucose and reduce the risk of adverse pregnancy outcomes in pregnant women with GDM. The Diabetes Prevention Program (DPP) showed that lifestyle intervention could reduce the risk of developing type 2 diabetes in patients with GDM by 35.2% [10]. Dietary intervention is generally considered the most basic non-drug intervention for patients with GDM, while exercise intervention is now receiving increasing attention [11,12]. Aerobic exercise refers to activities that increase heart rate by exercising large muscle groups within a certain period of time, including brisk walking, jogging, swimming, cycling, and aerobic exercise [13]. Previous studies have confirmed that

aerobic exercise has a positive effect on blood glucose control in patients with type 2 diabetes [14–16] and can also effectively reduce the risk of developing GDM in women in early pregnancy [7,17]. However, there are still limited studies on patients with GDM. At present, only seven studies have shown the effect of aerobic exercise intervention on the blood glucose levels, insulin levels, and maternal and infant pregnancy outcomes of GDM patients [18–24]. Even in these studies, the results are inconsistent. Some of the studies conducted exercise intervention in the way of giving guidance and suggestions to the subjects [20]. The outcome can only be achieved through telephone follow-up every week or every 2 to ask whether patients are adhering to the intervention plan. Given that these data are derived from patient self-report, it may be difficult to fully ascertain the results with accuracy. In addition, in some studies, only part of the exercise intervention was completed under the supervision of researchers, while some patients exercised at home independently [18–20].

At present, exercise guidelines for pregnant women in most countries recommend moderate exercise intensity during pregnancy [1,25,26]. Therefore, in this study, moderate-intensity indoor aerobic exercise with supervision was selected for exercise intervention, which is conducive to improving the safety of patients during exercise intervention. The purpose of this study is to ensure that exercise intervention is carried out under supervision, planning, and control to objectively evaluate the data. In this way, a more accurate analysis was carried out on the effects of moderate-intensity exercise on blood glucose, insulin, and pregnancy outcomes in GDM patients. In this way, the results might provide guidance for lifestyle intervention for GDM patients. The hypothesis of this study is that this aerobic exercise intervention can improve patients' blood glucose, insulin, and pregnancy outcomes.

METHODS

Research Design

In this study, the convenience sampling method was adopted to recruit GDM patients for prenatal follow-up in the high-risk obstetrics clinic and endocrinology department of a class 3 first-level general hospital from December 2019 to December 2020. A randomized controlled trial was conducted to investigate the effect of moderate aerobic exercise intervention on GDM patients.

Research Ethics

Before implementation, the trial was approved by the ethics committee of the hospital, and informed consent was obtained from all study subjects. The name of the institutional Ethics Committee that approved the research: the Second Affiliated to Fujian Medical University in China; approval number: 54. The date on which the approval was granted: December 3, 2019. The study was performed in accordance with the Declaration of Helsinki of 1964 and its later amendments.

Research Subjects

Inclusion criteria for subjects included: (1) diagnosis with GDM according to the OGTT test published by the International Association of Diabetes and Pregnancy Study Groups [27]; (2) having complete cognitive and behavioral ability; (3) age $\geq$ 20 years old; (4) body mass index (BMI) $<$ 40 kg/m^2; (5) single pregnancy; (6) gestational stage between 24 and 31 weeks and the upper limit of gestational stage at inclusion was set at 31 weeks to allow at least 6 weeks of intervention; (7) voluntary participation and informed consent. Exclusion criteria included: (1) previous diagnosis of diabetes; (2) previous history of abortion; (3) severe obstetric complications and contraindications listed in the 2019 Guidelines for Women's Activities during Pregnancy published by Canada [25]; (4) participation in other supervised and planned exercise programs or research during the study period.

Diagnostic criteria for GDM followed the Oral Glucose Tolerance Test (OGTT) published by The International Association of Diabetes and Pregnancy Study Groups (IADPSG) in 2010 [27], and the 75 g OGTT test was conducted during weeks 24–28 of pregnancy to determine the results. GDM was diagnosed when any of the following plasma glucose parameters were reached: fasting blood glucose (FBG) $\geq$ 5.1 and $<$ 7.0 mmol/l; 1-h postprandial blood glucose (PBG) $\geq$ 10.0 mmol/l; 2-h postprandial blood glucose $\geq$ 8.5 mmol/l and $<$ 11.1 mmol/l.

The research subjects were grouped by the simple random grouping method, and a set of random number sequences were generated by non-research group members (who did not know the content of the research design) using a web-based computerized procedure. The members put the random numbers into sequentially coded, sealed, and opaque envelopes. Finally, 51 cases were included in the experimental group and 50 cases in the control group.

Sample Size Calculation

The sample size formula is as follows:

$$N_1 = N_2 = 2[\sigma(T_{\alpha/2} + T_{\beta/2})/(\mu_- - \mu_2)]^2$$

In this study, the significance level $\alpha = 0.05$ and the test efficiency $1 - \beta = 0.8$ were set for the bilateral test. With reference to Brankston's study, the intervention measures and outcome indicators were similar to those in this study [28]. After intervention, the average blood glucose level at 2 h after three meals in the experimental group was 6.0 ± 0.29 mmol/l, which was lower than in the control group (6.4 ± 0.81 mmol/l). Thus, 38 patients were needed for each group. Assuming a 20% loss of follow-up rate, at least 48 subjects were needed in each group, and at least 96 subjects would eventually be needed in both groups.

Intervention Measures

Intervention Measures of the Experimental Group

(1) Moderate-intensity aerobic exercise: patients in the experimental group were given group exercise intervention in a special exercise room for pregnant women. Each intervention was carried out by three members of the research group, including the researcher who was assisted by a sports medicine expert. The experimental group was required to complete the exercise intervention three times per week for at least 6 weeks, with a total of at least 18 activities. In this study, the minimum acceptable number of exercises was set as 70% of the number of interventions in the study protocol from the time of enrollment to full-term pregnancy (37 weeks of gestation). That is, at least 13 interventions should have been completed [2]. The exercise time was set to 50–60 min, and the exercise intervention was in the form of aerobic exercise. Exercise included steps, neck extension, arm extension, leg movements, and movement of other body parts [29]. On site, sports medicine experts conducted organized exercise guidance for all the subjects and taught patients the basic movements [30]. During the first 2 weeks of intervention, each body part of the exercise was repeated twice under the guidance of sports medicine experts, and two sets of exercises were repeated. At the 3rd week, each part was repeated three times and two sets of exercises were repeated. From the 4th week to the delivery, each part was repeated for four times and two sets of exercises were repeated step by step. At the end of each exercise, patients would stretch for 5 min, followed by a short relaxation, to completely relax the muscles of the whole body [28,31]. Currently, exercise guidelines for pregnant women in most countries recommend moderate-intensity exercise [1,25,26]. According to American College of Sports Medicine (ACSM), moderate-intensity exercise is defined as having an absolute intensity of 3.0–5.9 mets, and Borg RPE scales are widely used to measure of perceived exercise intensity [32]. In the process

of intervention, the patient's heart rate was measured by an exercise bracelet, and moderate exercise intensity was assessed by the Brog Subjective Physical Sensation Scale combined with data from the exercise bracelet [1,25,26]. To maintain moderate intensity, subjects were required to monitor their heart rate during exercise and ensure that the heart rate did not exceed 140 beats/min [25]. However, in the Brog Subjective Physical Sensation Scale, women's score during moderate-intensity exercise is 13–14, which corresponds to the exercise perception of "a little hard" [30]. In the process of exercise intervention, to ensure the safety of patients, patients generally use the glucose meter uniformly configured in this study to measure peripheral blood glucose 1–2 h after eating the staple food, before starting the exercise plan, to prevent hypoglycemia [31]. In addition, patients were observed and treated in time if they had symptoms such as vaginal bleeding, dyspnea, and premature rupture of membranes during the intervention.

(2) Routine care included routine prenatal care, personalized diabetes diet guidance, and online education: (1) routine prenatal care: basic antenatal examination and the establishment of antenatal examination files during pregnancy; (2) personalized dietary guidance: one-to-one dietary guidance is provided by nutritionists and diabetes nurses according to blood sugar levels, BMI, and other conditions. Dietary knowledge manuals were distributed and explained through food models to teach patients how to match food and give guidance on weight control, blood glucose monitoring, food diary, and other aspects. (3) Online education included the establishment of an online public account providing knowledge of diet, exercise, and basic introduction of GDM.

Intervention Measures for the Control Group

The control group received the same routine prenatal care, personalized diabetes diet guidance, and online education intervention as the experimental group. In addition, the control group did not receive a unified, planned exercise intervention.

Evaluation Tools and Data Collection

All data from patients were collected for this study before, during, and after the intervention. Members of the research group that collected the data received training before the start of the study and did not know the grouping status of the patients. Baseline data of patients before the intervention included sociodemographic data and disease data related to GDM, such as parity number, history of cesarean section, family history of diabetes, current gestational age, current BMI, height, pre-pregnancy weight, and OGTT results. Data during and after the intervention included the measurement of fasting blood glucose levels and 2-h postprandial blood glucose every week during the 6 weeks of intervention. In addition, the pregnancy outcome and anthropometric data of mothers and newborns after delivery were collected after the intervention. Outcome indicators included:

(1) Fasting blood glucose levels and average blood glucose 2 h after three meals were measured. In this study, the glucose meter and blood glucose test paper were uniformly configured to measure blood glucose levels in peripheral capillaries of patients during the study period. Engineers maintained and calibrated the glucose meter every month to ensure the accuracy of the instrument. On the first day after the inclusion of the subjects, the researchers trained and taught the two groups of patients to conduct the method of self-measuring peripheral capillary blood glucose using the glucose meter to assess it on the spot. This was incorporated to ensure the accuracy of blood glucose monitoring in patients during the intervention.

(2) The number of people treated with insulin and the amount of insulin during the intervention were assessed. According to the American Diabetes Association guidelines [5], all patients in the control and experimental groups were initiated with insulin therapy if they consistently exceeded either of the following two glucose levels during the diet

and exercise interventions: fasting glucose levels of no more than 5.3 mmol/l and postprandial glucose levels of no more than 6.7 mmol/l.
(3) Maternal and infant pregnancy outcomes and complications during delivery included preterm delivery, prolonged labor, instrument delivery, cesarean section, macrosomia, neonatal BMI, neonatal Apgar score, premature rupture of membranes, neonatal asphoxia, and neonatal hypoglycemia.
(4) Adverse events were measured by the number of patients with adverse events during exercise intervention. It was assessed whether the patient experienced discomfort during exercise, including vaginal bleeding, eclampsia, dyspnea, headache, contractions, reduced fetal movement, premature rupture of membranes, palpitation, chest tightness, chest pain, and cyanosis.

Among the above outcome indicators, fasting blood glucose levels and average blood glucose levels at 2 h after three meals were the main outcome indicators, while other criteria were secondary outcome indicators.

Data Analysis Method

Excel 2013 and IBM SPSS 22.0 were used for data entry and statistical analysis. All variables were statistically described, and the measurement data were described as the mean ± standard deviation or median and quaternary. Counting data were described by frequency and percentage. For a baseline of intra- and inter-group comparisons of patients in the two groups, the t test was used for measurement data meeting normal distribution. The χ^2 test or Fisher's exact test was used for counting data. For all tests, $P < 0.05$ was considered statistically significant.

RESULTS

Comparison of General Data of GDM Patients Between the Two Groups

One hundred one cases were included in this study, including 50 cases in the control group and 51 cases in the experimental group. In the control group, four patients did not deliver in our hospital or chose to quit the study midway. In the experimental group, eight patients were lost to follow-up because of poor compliance with the exercise intervention. Therefore, 46 cases in the control group and 43 cases in the experimental group completed this study. The inclusion, grouping, and loss to follow-up of the subjects are shown in Fig. 1. No adverse events such as vaginal bleeding and dyspnea occurred in the experimental group during the exercise intervention. Two independent sample t tests, χ^2 test, and the Fisher exact probability test method were used to analyze the age, educational background, cesarean delivery, diabetes, family history, gestational stage, and statistical analyses of progestational general data (such as BMI) in the two groups. No statistically significant difference was found among the groups ($P > 0.05$; see Table 1).

Comparison of Fasting and 2-h Postprandial Blood Glucose Between the Two Groups of GDM Patients

Comparisons of Fasting and 2-h Postprandial Blood Glucose Before and After Intervention Between the Two Groups of GDM Patients

In this study, the paired t test was used to compare the average fasting blood glucose and average 2-h postprandial blood glucose levels of the experimental group and the control group before and after intervention. The differences were shown to be statistically significant ($P < 0.05$; see Table 2).

Comparison of Average Fasting and 2-h Postprandial Blood Glucose Levels Between the Two Groups of GDM Patients After Intervention

In this study, the t test of two independent samples was used to compare the average fasting blood glucose and the average blood glucose levels 2-h after three meals in the two groups of patients after intervention. The difference was statistically significant ($P < 0.05$; see Table 3).

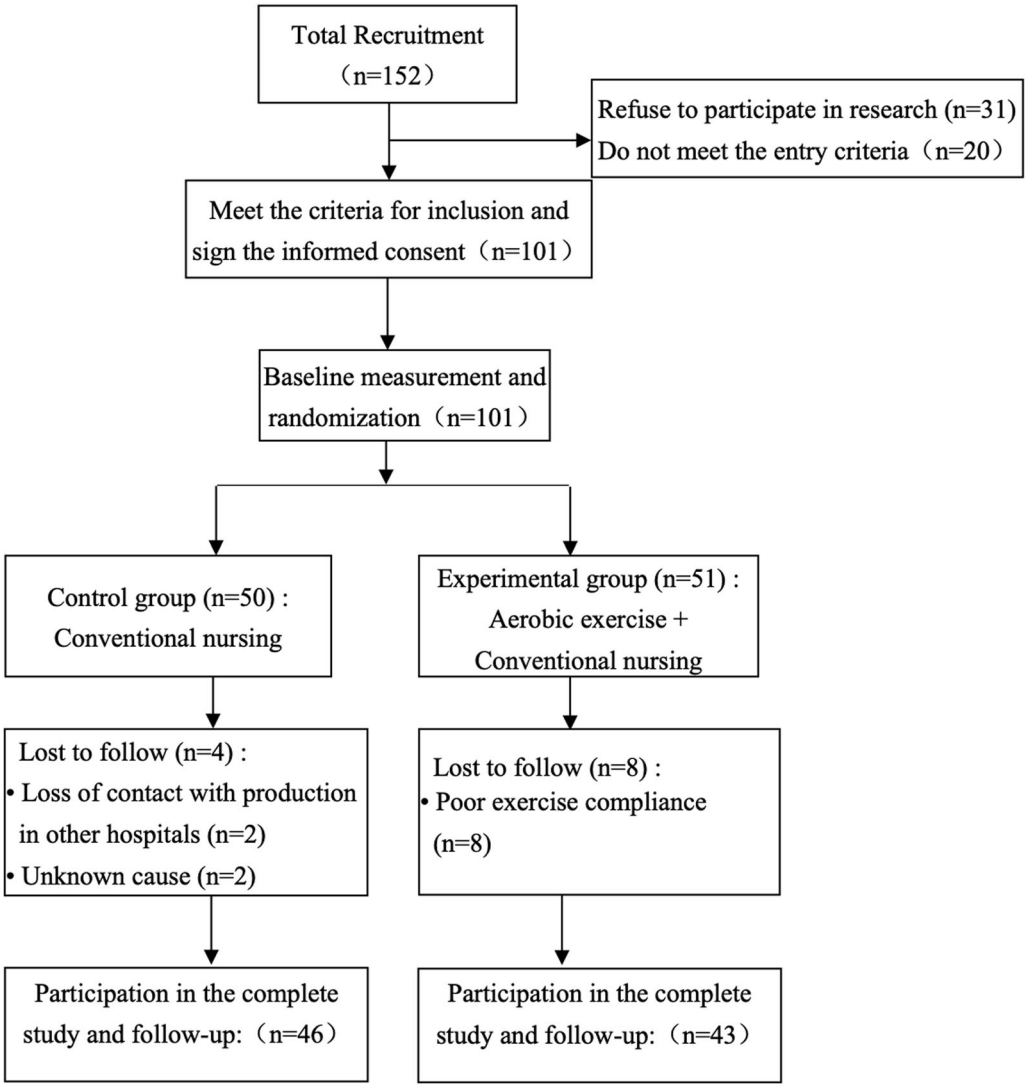

Fig. 1 Flow chart of the patients included in the study, grouped patients, and those lost to follow-up

Insulin Use in the Two Groups of GDM Patients During the Intervention

In this study, the Fisher's exact probability method and Wilcoxon rank sum test were used to compare insulin used by patients in the two groups during the intervention period. The differences were statistically significant ($P < 0.05$; see Table 4).

Comparison of Pregnancy Outcomes Between the Two Groups of GDM Patients

In this study, the χ^2 test, Fisher's exact probability method, and two independent sample t tests were used to compare the adverse pregnancy outcomes of the two groups of patients after intervention. The results showed that there was no statistical significance in the adverse maternal and infant outcomes between the two groups ($P > 0.05$; see Table 5).

Table 1 Comparison of general data from GDM patients between the two groups

Project	Control group $n = 46$	Experimental group $n = 43$	Test value	P
Age (years, $\bar{x} \pm s$)	31.35 ± 4.72	31.47 ± 4.06	− 0.125[a]	0.901
Education (n, %)	Primary to junior high school 5 (10.87%)	Primary to junior high school 5 (11.63%)	–	0.495
	Technical secondary school to junior college 25 (54.35%)	Technical secondary school to junior college 18 (41.86%)		
	Bachelor degrees or above 16 (34.78%)	Bachelor degrees or above 20 (46.51%)		
Parity number (parity,$\bar{x} \pm s$)	1.67 ± 0.63	1.53 ± 0.55	1.101[a]	0.274
History of cesarean section (n, %)	16 (34.8%)	8 (18.6%)	2.954[b]	0.086
Family history of diabetes (n, %)	8 (17.4%)	6 (14.0%)	0.198[b]	0.656
Current gestational age (weeks, $\bar{x} \pm s)\bar{x}$	28.02 ± 2.30	28.14 ± 2.00	− 0.257[a]	0.798
Height (meters,$\bar{x} \pm s$)	1.59 ± 0.04	1.60 ± 0.05	− 1.127[a]	0.263
Weight before pregnancy (kg, $\bar{x} \pm s$)	55.49 ± 8.02	59.25 ± 11.42	− 1.807[a]	0.074
BMI before pregnancy (kg/m^2, $\bar{x} \pm s$)	21.98 ± 2.96	23.08 ± 3.68	− 1.558[a]	0.123
Weight at diagnosis of GDM (kg, $\bar{x} \pm s$)	62.76 ± 9.46	65.11 ± 13.67	− 0.949[a]	0.345
Gestational age at diagnosis of GDM (weeks, $\bar{x} \pm s$)	25.17 ± 1.29	25.05 ± 1.33	0.460[a]	0.647
OGTT: fasting blood glucose (mmol/l, $\bar{x} \pm s$)	4.94 ± 0.49	4.93 ± 0.46	0.126[a]	0.900
OGTT: 1-h postprandial blood glucose (mmol/l, $\bar{x} \pm s$)	10.31 ± 1.67	10.01 ± 1.28	0.928[a]	0.356
OGTT: 2-h postprandial blood glucose (mmol/l, $\bar{x} \pm s$)	8.76 ± 1.38	8.56 ± 1.17	0.750[a]	0.455
Pre-intervention fasting blood glucose (mmol/l, $\bar{x} \pm s$)	5.29 ± 0.54	5.28 ± 0.61	0.035[a]	0.972
Pre-intervention 2-h postprandial blood glucose (mmol/l, $\bar{x} \pm s$)	6.58 ± 0.73	6.48 ± 0.41	0.838[a]	0.405

A is T value, B is χ^2 value, – is Fisher's exact probability method

Table 2 Comparison of fasting and 2-h postprandial blood glucose levels in two groups before and after intervention

Project	Control group $n = 46$	t	P	Experimental group $n = 43$	t	P
Mean fasting glucose (mmol/l, $\bar{x} \pm s$)	Before intervention5.29 ± 0.54	2.555	0.014	Before intervention5.28 ± 0.61	3.976	0.000
	After intervention5.08 ± 0.17			After intervention4.92 ± 0.15		
Mean 2-h postprandial blood glucose (mmol/l, $\bar{x} \pm s$)	Before intervention6.58 ± 0.73	3.216	0.002	Before intervention6.48 ± 0.41	5.994	0.000
	After intervention6.25 ± 0.22			After intervention6.11 ± 0.11		

Table 3 Comparison of blood glucose levels after intervention between the two groups of GDM patients

Project	Control group $n = 46$	Experimental group $n = 43$	t	P
Mean fasting glucose (mmol/l, $\bar{x} \pm s$)	5.08 ± 0.17	4.92 ± 0.15	4.694	0.000
Mean 2-h postprandial blood glucose (mmol/l, $\bar{x} \pm s$)	6.25 ± 0.22	6.11 ± 0.11	3.854	0.000

Table 4 Comparison of insulin use during intervention between the two groups of GDM patients

Project	Control group $n = 46$	Experimental group $n = 43$	Test value	P
Insulin utilization rate (n, %)	8 (17.4%)	1 (2.3%)	–	0.031
Usage of insulin (u/d,$\bar{x} \pm s$)	2.05 ± 5.04	0.28 ± 1.83	− 2.33[a]	0.02

A is Z value; – is Fisher's exact probability method

DISCUSSION

The purpose of this study was to investigate the effects of structured moderate-intensity aerobic exercise intervention on blood glucose, insulin, and pregnancy outcomes in patients with gestational diabetes mellitus. This is not the first study to investigate the effects of aerobic exercise on blood glucose control in pregnant women with GDM. However, compared with previous studies, the present report strictly controlled the exercise intensity of patients, conducted on-site supervision and intervention, and effectively controlled the quality of exercise intervention. Thus, the results presented in this report may be more a more accurate representation.

Comparison of Fasting and 2-h Postprandial Blood Glucose Levels Between the Two Groups of GDM Patients

These results on fasting blood glucose and 2-h postprandial blood glucose levels of patients in both groups indicate that both moderate aerobic exercise and dietary intervention for diabetes are beneficial to reduce blood glucose levels in patients with GDM. However, increasing exercise intervention on the basis of dietary control has a better effect on blood glucose control. This study is consistent with the previous studies on aerobic exercise in patients with GDM [33,34] and is also consistent with previous reports on patients with type 2 diabetes [14–16]. Irrespective of patients with type 2 diabetes or GDM, aerobic exercise can

Table 5 Comparison of pregnancy outcomes between the two groups of GDM patients

Project	Control group (n = 46)	Experimental group (n = 43)	Test value	P
Premature rupture of membranes (n, %)	8 (17.39%)	9 (20.93%)	0.180[b]	0.671
Preterm birth (n, %)	4 (8.70%)	1 (2.3%)	–	0.362
Prolonged labor (n, %)	0	1 (2.3%)	–	0.483
Cesarean section (n, %)	24 (52.17%)	16 (37.21%)	2.011[b]	0.156
Macrosomia (n, %)	3 (6.52%)	3 (7%)	–	1.000
Newborn weight (g, $\bar{x} \pm s$)	3126.30 ± 420.86	3237.91 ± 419.05	− 1.253[a]	0.214
Newborn body length (cm, $\bar{x} \pm s$)	50.11 ± 1.06	49.88 ± 0.66	1.192[a]	0.236
Neonatal BMI (kg/m^2,$\bar{x} \pm s$)	12.41 ± 1.28	12.99 ± 1.47	− 1.976[a]	0.051
Neonatal 1 min Apgar (points,$\bar{x} \pm s$)	9.63 ± 0.97	9.72 ± 1.18	− 0.395[a]	0.694
Neonatal 5 min Apgar (points,$\bar{x} \pm s$)	9.89 ± 0.31	9.93 ± 0.34	− 0.563[a]	0.575
Neonatal 10 min Apgar (points,$\bar{x} \pm s$)	9.98 ± 0.15	10 ± 0.00	− 0.966[a]	0.336
Neonatal asphyxia (n, %)	2 (4.35%)	1 (2.3%)	–	1.000
Neonatal hypoglycemia (n, %)	1 (2.17%)	0	–	1.000

A is T value, B is χ^2 value, – is Fisher's exact probability method

enhance the utilization and uptake of glucose by muscle cells by enhancing insulin activity, promoting glucose phosphorylation in muscle cells, transforming blood glucose to myosaccharide, and ultimately reducing blood glucose concentrations [35,36]. In patients with type 2 diabetes, there have been studies comparing the effects of different forms of aerobic exercise and resistance training [14]. However, for patients with GDM, there are limited studies exploring the most effective aerobic exercise program. Since there is more than one type of exercise available for patients with GDM, the best type of aerobic and anti-resistance exercises need to be determined to provide the best prevention strategies for GDM.

Insulin Use in the Two Groups of GDM Patients During the Intervention

These results on the utilization and use of insulin of patients in both groups indicate that moderate-intensity aerobic exercise had a positive effect on the needed blood glucose levels of patients with GDM, thus reducing the number of insulin treatments and the dosage. Davenport et al. also pointed out that a structured aerobic brisk walking program played an effective role in the blood glucose regulation of patients with GDM, requiring less insulin each day [22]. However, the insulin findings in the present report are inconsistent with other studies [19] that varied in the length of the intervention and the type of aerobic exercise. Insulin use reflects the status of impaired blood glucose levels in patients in conjunction with aerobic exercise, which regulates the secretion of pancreatic islet cells, promoting glucose metabolism in patients with GDM. In this way, exercise improves insulin resistance and metabolic abnormalities such as blood glucose levels and lipids [37]. Eight people in this study withdrew because of poor exercise compliance. Therefore, it is necessary to explore ways to incentivize this form of exercise in the future. Specific sports and fitness programs can be designed according to the physical characteristics of different individuals, personal preferences, and even habits for selection. Clinical

staff can construct safe and fun exercise prescriptions to meet the musculoskeletal limitations and exercise preferences of GDM patients during pregnancy, including mode, timing, exercise intensity, exercise frequency, and exercise time. In this way, patients may be more interested in participating in a regular exercise program [38].

Comparison of Pregnancy Outcomes Between the Two Groups of GDM Patients

Although domestic and foreign scholars previously used meta-analysis to elucidate the influence of various forms of exercise intervention on pregnancy outcomes in GDM patients, the results do not conclusively indicate that aerobic exercise can reduce the risk of maternal and infant adverse outcomes such as macrosomia and cesarean section in GDM patients [34,39]. The results are still controversial. Aerobic exercise regulates blood glucose, adiponectin and leptin levels in GDM patients, increases insulin activity, increases glucose uptake and utilization, and maintains the balance of glucose and insulin secretion [35,36]. Pregnancy outcomes of the two groups of patients were compared, and the results showed that there was no statistical significance in the maternal and infant pregnancy outcomes of the two groups. However, due to the small sample size of this study, it is difficult to directly conclude that aerobic exercise has no effect on pregnancy outcomes. The average fasting blood glucose and 2-h postprandial blood glucose levels of patients in the experimental group were lower than in the control group during intervention. Therefore, the incidence of adverse pregnancy outcomes is likely to be lower in the experimental group than in the control group. To further verify the results, a multicenter study with a large sample size would be beneficial. Future studies should include a longer follow-up to observe the health of both groups of patients and neonates to evaluate the long-term effects of aerobic exercise on patients with GDM and to further clarify the association with type 2 diabetes.

Security

At present, most countries recommend moderate-intensity exercise for pregnant women [1,25,26]. In this study group during the period of moderate-intensity aerobic exercise, there was no bleeding, no observed difficulty breathing, no headache or other adverse events. Thus, the data showed that moderate exercise for GDM pregnant women is natural and safe. At present, there is no evidence indicating that aerobic exercise in patients with GDM will have adverse effects on mothers and infants. Moderate exercise does not increase the risk of adverse pregnancy outcomes such as cesarean section, macrosomia, and neonatal hyperbilirubinemia [18–24]. In addition, studies have indicated that not doing any exercise during pregnancy can increase the risk of depression and pregnancy hypertension [39–41], indicating that moderate exercise during pregnancy for GDM patients is both safe and beneficial.

Limitations

Due to the limitations in funds, resources, and research assistance, this study was restricted to one hospital with a minimal sample size. The study did not incorporate GDM patients in various regions and thus did not have multicenter cooperation. The study was voluntary, so it is likely to be limited to people with GDM who have a better understanding of their condition and are more willing to cooperate with lifestyle changes. Although the control group did not receive a unified, planned exercise intervention, the patients in this group were not forbidden to do other exercise at home, but it is difficult to make statistical comparison on whether the patients had exercise autonomously after going home.

Future Research Directions

The following suggestions are proposed for future research directions: To further verify the results, a multicenter study with a large sample size would be beneficial. A postpartum, long-term follow-up is needed to further verify the

long-term effects of aerobic exercise intervention on maternal and infant health and wellness. Future studies should also consider possible high-risk pregnant women with GDM for early intervention and prevention of GDM. In addition, no studies have determined the best aerobic exercise regimen for pregnant women with GDM. There are many types of exercises available for GDM patients, and the best type of aerobic exercise regimen should be determined in the future. These studies could consider a combination of aerobic and resistance exercises to determine the most effective exercise regimen.

CONCLUSIONS

The results of this study showed that moderate-intensity structured aerobic exercise could improve the fasting blood glucose and 2-h postprandial blood glucose levels, insulin utilization rate, and insulin dosage in patients with GDM, but did not significantly improve adverse pregnancy outcomes. In the future, long-term follow-up on maternal and infant health can be conducted to explore the long-term effects of aerobic exercise intervention.

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Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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