Effects of resistance exercise on blood glucose level and pregnancy outcome in patients with gestational diabetes mellitus: a randomized controlled trial

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ABSTRACT

Introduction To date, the effects of resistance exercise on diabetes-related parameters (blood glucose level and insulin use) and pregnancy outcome in participants with gestational diabetes mellitus (GDM) have not been compared with those of aerobic exercise. To investigate the effect of resistance exercise versus aerobic exercise on blood glucose level, insulin utilization rate, and pregnancy outcome in patients with GDM.

Research design and methods From December 2019 to December 2020, 100 pregnant women with GDM were selected and divided into a resistance exercise group (49 patients) and an aerobic exercise group (51 patients) randomly. The aerobic exercise group received an aerobic exercise intervention, while the resistance exercise group received a resistance exercise intervention. Both groups received exercise intervention for 50–60 min, 3 times per week, lasting for 6 weeks. In addition, patients in both groups received the same routine care, including personalized dietary intervention, online education, and school courses for pregnant women.

Results The blood glucose level in the resistance exercise group and the aerobic exercise group was lower after the intervention than before the intervention (p<0.05). After the intervention, no significant differences were observed in the fasting blood glucose level, insulin utilization rate, and incidence of adverse pregnancy outcomes between the two groups (p>0.05); however, significant differences were noted in 2-hour postprandial blood glucose level and exercise compliance between the two groups (p<0.05), with the resistance exercise group showing better outcomes than the aerobic exercise group.

Conclusions Resistance exercise is more compliant for pregnant women with GDM than aerobic exercise; hence, it is necessary to popularize resistance exercise in this specific population group. Long-term effects of resistance exercise should be evaluated in future studies.

Trial registration number ChiCTR 1900027929.

Significance of this study

What is already known about this subject?
► Globally, gestational diabetes mellitus (GDM) incidence is increasing each year.
► GDM can increase the risk of adverse outcomes and type 2 diabetes mellitus (DM) in pregnant women and their offspring.
► Comparison of the effects of aerobic exercise and resistance exercise on improving hemoglobin A1c levels in patients with type 2 DM has been reported; however, such comparison in patients with GDM is lacking.

What are the new findings?
► The effects of moderate intensity aerobic exercise and resistance exercise on patients with GDM were compared.
► The resistance exercise group showed better postprandial blood glucose and exercise compliance than the aerobic exercise group.
► Resistance exercise is a feasible non-drug intervention for patients with GDM.

How might these results change the focus of research or clinical practice?
► Early intervention in pregnant women at high risk for GDM can be used to determine whether resistance exercise helps to prevent the development of GDM.
► Detailed studies on the form, intensity, and frequency of the best type of resistance exercise should be conducted to determine effective prevention strategies.

INTRODUCTION

Gestational diabetes mellitus (GDM) refers to any degree of abnormal glucose tolerance first detected during pregnancy,[1] and it accounts for approximately 90%–95% of the total number of women with hyperglycemia during pregnancy.[2] The incidence of GDM is increasing each year worldwide, and the prevalence in low-income and middle-income countries has increased by >30% in the last 20 years.[3] GDM can lead to increased risk of adverse pregnancy outcomes such as preterm delivery, fetal respiratory distress, and fetal macrosomia,[4 5] and significantly increases the risk of type 2 diabetes mellitus (DM) in pregnant women at 5–10 years after delivery[6]

and the risk of obesity and diabetes in offspring.[7] So, it is critical to prevent the adverse outcomes of GDM on pregnant women.

A Diabetes Prevention Program (DPP) study showed that lifestyle intervention can reduce the incidence of developing diabetes in patients with GDM by 35.2%.[8] Dietary intervention is usually the most basic lifestyle intervention for patients with GDM, and exercise intervention includes aerobic and resistance exercise.[9] Aerobic exercise is activity that raises your heart rate by working large muscle groups for a certain amount of time, including cycling, jogging, and brisk walking,[10] most of which require patients to conduct a wide range of whole-body muscle activities outdoors. Researchs have shown that aerobic exercise has an effective effect on the blood glucose level, insulin dosage, and pregnancy outcome of patients with GDM.[11]

Compared with aerobic exercise, resistance exercise is a relatively new exercise intervention for patients with GDM and has been used only recently in these patients. Consequently, there are very few studies on the application of this exercise in this population group in China and abroad. Resistance exercise involves an autonomous exercise in which large muscle groups are contracted by overcoming external resistance in the resting state, which helps to exercise skeletal muscle and reduce fat content, and it is not subject to venue and seasonal restrictions.[12] At present, relevant studies[13–15] have confirmed that this exercise is helpful to promote insulin secretion and reduce blood glucose level and the incidence of adverse pregnancy outcomes in patients with GDM.

To date, the effects of aerobic exercise and resistance exercise on improving hemoglobin A1c levels have been compared in patients with type 2 DM[16]; however, similar comparison studies of the effects of these two types of exercises on patients with GDM are lacking in China and abroad. Aerobic exercise is currently more prevalent in this population than resistance exercise; however, resistance exercise might be easier to perform for patients with GDM. Because women generally undergo GDM screening at 24–28 weeks of gestation,[4] the fetus in this stage is growing continuously in the mother, and its physical load on the mother causes limited activity,[15] this is particularly true for pregnant women with GDM who need to stay in bed to protect the fetus. Consequently, it becomes difficult for these women to perform aerobic exercise with a large range of activity at this time. Resistance exercise can be performed at home or even in bed by exerting force on the body to carry out basic movement exercises. The movement process is relatively stable, which helps to avoid the discomfort caused by the forward shift of the center of gravity in late pregnancy; thus, patients with GDM may find it more comfortable and easier to adhere to a resistance exercise program.[13] The present study aimed to investigate the effect and compliance difference between resistance exercise and aerobic exercise for patients with GDM, so that these patients can have a complete understanding of resistance exercise and choose more different exercise methods; it will also help to promote the application of resistance exercise in patients with GDM. The hypothesis of this study is that resistance exercise induces effects that are comparable to those of aerobic exercise on blood glucose level, insulin usage, and adverse pregnancy outcomes in patients with GDM.

RESEARCH METHODS
Research design
In this study, from December 2019 to December 2020, a convenience sampling method was used to enroll patients with GDM who came for prenatal follow-up in the high-risk obstetrics department and endocrinology department in a class 3 first-level general hospital in China. A randomized controlled trial was conducted to compare the effects of resistance exercise and aerobic exercise on patients with GDM. This research team is mainly engaged in the exercise and diet research of GDM and the methods of the study is similar to our previously published work.[17]

Research subjects
Inclusion criteria for study subjects were as follows: (1) those diagnosed with GDM on the basis of the oral glucose tolerance test, which was published by the International Association of Diabetes and Pregnancy Study Groups in 2010;[18] (2) age between 20 and 40 years; (3) gestational age between 24 and 31 weeks, with the upper limit of gestational age at inclusion set at 31 weeks to allow for at least 6 weeks of intervention; (4) single pregnancy; (5) body mass index (BMI) <40 kg/m^2; and (6) having complete cognitive and behavioral abilities. Exclusion criteria were as follows: (1) previous abortion history; (2) participation in other planned and supervised exercise programs or research activity during this research period; and (3) patients with severe obstetric contraindications and complications listed in the Canadian Guidelines for the Activities of Pregnant Women.[19]

Non-members of the research group (who were unaware of the research design) used the SPSS software program to generate a set of random number sequences. The research group members input the random numbers into sequentially coded, opaque, and sealed envelopes. The random numbers were arranged in odd or even groups, with the odd number as the resistance exercise group and the even number as the aerobic exercise group. Finally, 49 patients were included in the resistance exercise group, and 51 patients were included in the aerobic exercise group.

Sample size
The present study referred to the study by Brankston *et al*, whose intervention measures and outcome indicators were similar to those of the present study, and the sample size was calculated based on blood glucose indicators.[13] The significance level α=0.05 and the test efficiency 1−β=0.8 were set for bilateral test. So, 38 patients were

required in each group. Assuming a 20% lost to follow-up rate, 48 subjects would be needed for inclusion in each group.

Intervention

Exercise intervention

The two groups of participants underwent different exercise intervention measures: the resistance exercise group adopted the resistance exercise intervention, while the aerobic exercise group adopted the aerobic exercise intervention. A face-to-face interview with the patients was conducted in this study. Because the exercise plan of the patients in this study requires them to visit the maternity activity classroom of the hospital for exercise, the interviews were conducted after each exercise session. The two groups of patients received group exercise intervention in different activity rooms for pregnant participants. Each intervention was performed by three members of this research group, and assisted by a sports medicine expert. The intervention period was at least 6 weeks in duration, spanning from the diagnosis of GDM to the delivery of child. To ensure that patients in the two groups received equal attention, the frequency, interval, intensity, timing and duration of exercise were as consistent as possible.[13 14] Patients in both groups were required to perform at least 18 activities 3 times per week for 6 weeks. In the research, the minimum acceptable number of exercises during the period from enrollment to full-term pregnancy (37 weeks gestation) was set as 70% of the number of interventions, that is, at least 13 interventions were completed.[2] The exercise intervention in the aerobic exercise group was performed as aerobic exercise, which mainly included step walking, neck stretching exercise, arm stretching exercise, leg exercise, etc.[20] In the resistance exercise group, resistance exercises for upper and lower limb muscle training were adopted, including elbow flexion exercise, ankle extension exercise, resistance exercise of the upper limb, leg lift exercise, upper limb dorsiflexion exercise, and leg abduction exercise.[13 14] On site, the sports medicine experts provided organized exercise guidance to the patients and taught the basic movements of this sport.[21] The exercise session was set to 50–60 min in accordance with the guidelines of the American College of Obstetricians and Gynecologists for exercise during pregnancy and post partum.[1] At the end of each session, the patients were allowed to stretch for 5 min, followed by a short relaxation session to completely relax all the muscles. During the first 2 weeks of the intervention, two sets of exercises were repeated twice for each body part. In the third week, exercise for each body part was repeated 3 times and two sets of exercises were performed. From the fourth week to the delivery, exercise for each body part was repeated 4 times and two sets of exercises were performed.

Exercise guidelines for pregnant women in most countries recommend moderate intensity exercise.[1 19 22] Therefore, in the intervention process, the heart rate of patients was measured using an exercise bracelet. Moderate exercise intensity was assessed using the subjective rating of perceived exertion (Borg Scale) combined with the readings from the exercise bracelet.[1 19 22] Subjects are required to monitor heart rate during exercise, then ensure that the heart rate does not exceed 140 beats/min to maintain moderate intensity.[19] In Borg Scale, women's score of moderate intensity during exercise should reach 13–14, which corresponds to the perception of movement involving 'a little exertion'.[21] During the intervention process, the patients were observed for any adverse events such as dyspnea, premature rupture of membranes, vaginal bleeding and other uncomfortable symptoms; if such adverse events occurred, the patients were asked to stop exercising and received timely treatment from gynecologists and endocrinologists in the research team.

Routine nursing measures

Patients in both groups received the same routine nursing measures, including personalized dietary intervention, online education, and school courses for pregnant women. Dietitians and nurses for patients with diabetes developed individualized dietary intervention plans according to the blood glucose level, BMI, and other health conditions of the patients. The patients were simultaneously educated on blood glucose monitoring, weight control, maintenance of food diary, and other dietary aspects. The basic principles of the diet were in accordance with the nutritional guidelines of the American Diabetes Association:[2] the diet consisted of 50% carbohydrates, 20% protein, and 30% fat and was divided between three main meals and three snacks per day. The research group members established an online public account for providing pregnancy-related knowledge and formed WeChat groups for both groups of patients. Open school courses for pregnant women included scientific confinement, neonatal breast feeding, and other details related to pregnancy and childbirth.

Observation indices

The observation data of the patients during the study period were collected by the team members, the medical staff in the obstetric clinic, and the ward staff. The relevant personnel were trained before data collection, and the data collectors were blinded to the grouping and intervention of this study.

A self-designed questionnaire was used to collect general information of participants before the intervention, including basic information and disease-related information. Among the observation indicators during the intervention, blood glucose level was the primary outcome, while other parameters were secondary outcome. The following indicators were monitored: (1) blood glucose level: fasting blood glucose level and average blood glucose level at 2 hours after three meals were measured. The glucose meter and the test strips were uniformly

configured to measure the blood glucose level of patients, and the technicians calibrated and maintained these glucose meter each month. During the intervention, all patients were required to measure blood glucose levels regularly, and each measurement value included the fasting level and the 2-hour postprandial level after three meals; (2) patient compliance: the number of visits to the hospital for exercise intervention during the study period was recorded to evaluate exercise compliance of the patients. To ensure the optimal effect of the intervention, patients were required to complete at least 13 interventions[2]; (3) adverse events: the number of adverse events that occurred during the exercise intervention was recorded, particularly regarding whether the patients experienced discomfort during the intervention; (4) insulin use: the number of patients using insulin during the intervention and the amount of insulin used in the two groups were monitored. According to Guidelines of the American Diabetes Association,[4] insulin therapy was initiated for all patients in the two groups if they consistently exceeded any of the target blood glucose values during the exercise and diet intervention program: fasting blood glucose level did not exceed 5.3 mmol/L, and 2-hour postprandial blood glucose level did not exceed 6.7 mmol/L. Insulin treatment was tailored by the team's endocrinologists and obstetricians. If patients are still hyperglycemic 1 week after the intervention, they are treated with insulin, usually with basal-bolus and insulin dose is calculated based on blood glucose and body weight. For the estimation of mean glucose, at least seven determinations were considered. Patients were required to continue monitoring their blood glucose levels during insulin treatment. For patients with exercise and diet control, if the blood glucose level did not meet the standard, insulin treatment was required throughout the pregnancy; and (5) pregnancy outcome: maternal and neonatal complications during delivery were recorded.

Data analysis

Microsoft Excel 2013 and IBM SPSS Statistics V.22.0 software were used for data entry and statistical analysis. First, all variables of baseline data were statistically defined, and measurement data were expressed as mean±SD or median and IQR. Count data were expressed as frequency and percentage. Paired t-tests were used to compare blood glucose levels before and after the intervention. Comparison of baseline and intervention data between the groups was performed as follows: for normally distributed measurement data such as blood glucose level and insulin use, two independent samples t-tests were performed. Count data related to adverse pregnancy outcomes such as preterm delivery were analyzed using the χ^2 test or Fisher's exact test. For all tests, $p < 0.05$ was considered to be statistically significant.
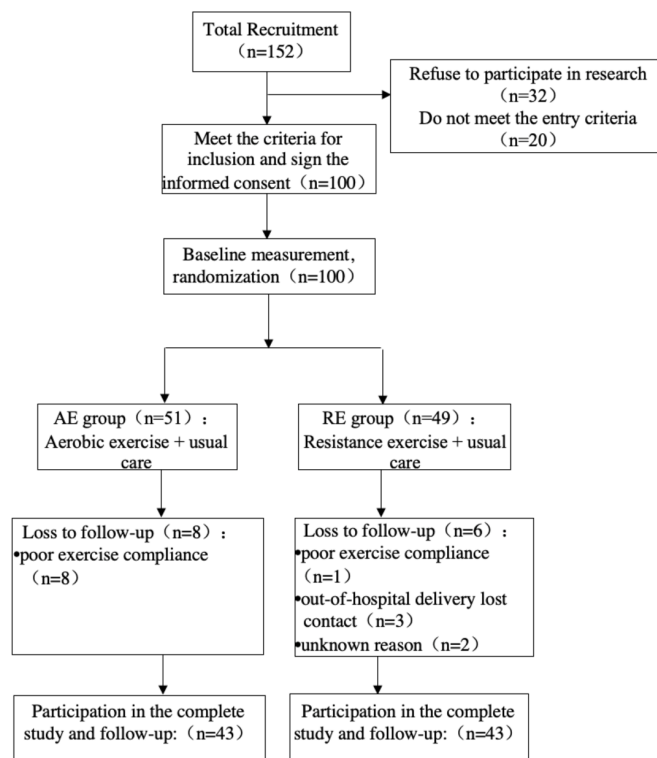

Figure 1 Flow chart of patients included, grouped, and lost to follow-up. AE, aerobic exercise; RE, resistance exercise.

RESULTS

Comparison of general data of patients with GDM between the two groups

This study included 100 patients, of whom 49 patients were included in the resistance exercise group and 51 patients in the aerobic exercise group. In the resistance exercise group, one patient was lost to follow-up due to poor intervention compliance, and five patients did not deliver in this hospital or chose to withdraw from the program midway. Eight patients in the aerobic exercise group were lost to follow-up due to poor intervention compliance. Therefore, 43 patients in each group completed this study. The flow chart of patient inclusion and grouping is shown in figure 1. No adverse events such as vaginal bleeding occurred in both groups during the intervention period. There was no significant difference in general data between the two groups (p>0.05) (table 1). Forty-eight patients (97.96%) and 43 patients (84.31%) satisfied the compliance standards in the resistance exercise and aerobic exercise groups, respectively. The difference in compliance between the two groups was statistically significant (p=0.031).

Comparison of fasting and 2-hour postprandial blood glucose levels between the two groups

Blood glucose levels before and after the intervention between the two groups

A paired t-test was used to compare the average peripheral fasting blood glucose level (t=2.090, p=0.043) and the average 2-hour postprandial blood glucose level (t=4.758, p<0.001) in the resistance exercise group

Table 1 Comparison of general characteristics of patients with GDM between the two groups

Project	RE group n=43	AE group n=43	Test value	P value
Age (years, $\overline{x}\pm s$)	31.84±5.19	31.47±4.06	0.370*	0.712
Education (n, %)	Primary school 2 (4.6) Junior high school 6 (14.0) Technical secondary school to high school 7 (16.3)	Primary school 0 (0.0) Junior high school 5 (11.6) Technical secondary school to high school 3 (7.0)	−†	0.229
	College and above 28 (65.1)	College and above 35 (81.4)		
Parity number (parity, M, IQR)	1 (1–2)	2 (1–2)	0.501*	0.617
Family history of diabetes (n, %)			1.833‡	0.176
Yes	11 (25.6)	6 (14.0)		
No	32 (74.4)	37 (86.0)		
History of cesarean section (n, %)			1.042‡	0.307
Yes	12 (27.9)	8 (18.6)		
No	31 (72.1)	35 (81.4)		
Current gestational age (weeks, $\overline{x}\pm s$)	28.02±2.01	28.14±2.00	−0.270*	0.788
Height (m, $\overline{x}\pm s$)	1.60±0.05	1.60±0.05	−0.023*	0.982
Weight before pregnancy (kg, $\overline{x}\pm s$)	59.43±15.78	59.25±11.42	0.061*	0.951
BMI before pregnancy (kg/m², $\overline{x}\pm s$)	23.03±5.22	23.08±3.68	−0.050*	0.960
Gestational age at diagnosis of GDM (weeks, $\overline{x}\pm s$)	25.30±1.61	25.05±1.33	0.804*	0.424
Weight at diagnosis of GDM (kg, $\overline{x}\pm s$)	65.67±12.57	65.11±13.67	0.196*	0.845
OGTT: fasting blood glucose (mmol/L, $\overline{x}\pm s$)	5.05±0.51	4.93±0.46	1.167*	0.247
OGTT: 1-hour postprandial blood glucose (mmol/L, $\overline{x}\pm s$)	10.09±1.40	10.01±1.28	0.283*	0.778
OGTT: 2-hour postprandial blood glucose (mmol/L, $\overline{x}\pm s$)	8.48±1.28	8.56±1.17	−0.291*	0.772
Pre-intervention fasting blood glucose (mmol/L, $\overline{x}\pm s$)	5.29±0.65	5.28±0.61	0.063*	0.950
Pre-intervention 2-hour postprandial blood glucose (mmol/L, $\overline{x}\pm s$)	6.53±0.51	6.48±0.41	0.527*	0.599

*t-value.
†Fisher's exact test.
‡X^2 value.
AE, aerobic exercise; BMI, body mass index; GDM, gestational diabetes mellitus; OGTT, glucose tolerance test; RE, resistance exercise.

before and after the intervention, and the differences were statistically significant. And a paired t-test was also used to compare the fasting blood glucose level (t=2.236, p=0.031) and the 2-hour postprandial blood glucose level (t=3.789, p<0.001) of the aerobic exercise group before and after the intervention, and the difference was statistically significant. The results for both groups are shown in table 2.

Blood glucose level after the intervention between the two groups

Two independent samples t-tests were performed to compare the average peripheral fasting blood glucose

Table 2 Comparison of blood glucose levels in the two groups before and after intervention

Parameter	RE group n=43	t-test	P value	AE group n=43	t-test	P value
Mean fasting glucose (mmol/L, $\overline{x}\pm s$)	Before intervention 5.29±0.65	2.090	0.043	Before intervention 5.28±0.61	2.236	0.031
	After intervention 5.08±0.29			After intervention 5.05±0.31		
Mean 2-hour postprandial blood glucose (mmol/L, $\overline{x}\pm s$)	Before intervention 6.53±0.51	4.758	0.000	Before intervention 6.48±0.41	3.789	0.000
	After intervention 6.03±0.34			After intervention 6.19±0.31		

The number of determinations of the mean fasting glucose levels in the RE group and the AE group before intervention was 43 and 49, respectively. The number of determinations of 2-hour postprandial blood glucose level in the RE group and the AE group was 128 and 135, respectively. The number of determinations of the mean fasting glucose levels in the RE group and the AE group after intervention was 301 and 295, respectively. The number of determinations of 2-hour postprandial blood glucose level in the RE group and the AE group was 900 and 888, respectively.

AE, aerobic exercise; RE, resistance exercise.

level of patients in two groups after the intervention, and the difference was not statistically significant (t=0.506, p=0.614); however, the difference in the average 2-hour postprandial blood glucose level between the two groups was statistically significant (t=−2.384, p=0.019). The results are shown in table 3.

Insulin use in the two groups during the intervention

Fisher's exact test was used to compare the number of patients using insulin between the two groups during the intervention. The results showed no statistically significant difference in insulin use between the two groups during the intervention (p=1.000), with one patient in each group (2.3%) using insulin during the intervention. The mean insulin use was 14.19 and 12.04 U/day in the resistance exercise and aerobic exercise groups, respectively.

Comparison of pregnancy outcomes between the two groups

In the present study, the χ^2 test, Fisher's exact test, and two independent samples t-tests were used to compare adverse pregnancy outcomes of patients in the two groups after the intervention and after loss to follow-up. The results showed no significant difference in pregnancy outcomes between the two groups (p>0.05). The 10 min Apgar score for newborns was 10 in both groups. The results are shown in table 4.

DISCUSSION

Moderate intensity exercise is safe for patients with GDM, and compliance to resistance exercise is higher than that to aerobic exercise

In the present study, nine patients showed low exercise compliance, including one patient in the resistance exercise group and eight patients in the aerobic exercise group. The results showed that exercise compliance in the resistance exercise group was better than that in the aerobic exercise group (p=0.031). According to previous studies, the main exercise methods for patients with GDM are still aerobic and resistance exercise. However, for patients with GDM in late pregnancy, the physical load caused by the fetus to the mother limits their activities, thereby making it difficult for them to perform aerobic exercise, whereas resistance exercise can be carried out in sitting position or even while lying on the bed through basic movement exercises. Thus, resistance exercise might be a better option for patients with GDM to perform exercise.[23] Therefore, it is necessary to promote the use of resistance exercise in future clinical practice.

In this study, no adverse events such as dyspnea occurred in the two groups of patients during the exercise intervention period; this also indicates that moderate intensity exercise is safe for women with GDM. Presently, there is no evidence that resistance exercise or aerobic exercise causes adverse effects on women with GDM and

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

Parameter	RE group n=43	AE group n=43	t-test	P value	Glycemic levels within the targets
Mean fasting glucose (mmol/L, $\overline{x}\pm s$)	5.08±0.29	5.05±0.31	0.506	0.614	97.67%
Mean 2-hour postprandial blood glucose (mmol/L, $\overline{x}\pm s$)	6.03±0.34	6.19±0.31	−2.384	0.019	97.67%

AE, aerobic exercise; GDM, gestational diabetes mellitus; RE, resistance exercise.

Table 4 Comparison of pregnancy outcomes between the two groups of patients with GDM

Parameter	RE group, n=43	AE group, n=43	Test value	P value
Premature rupture of membranes (n, %)	6 (14.0)	9 (20.9)	0.727*	0.394
Preterm birth (n, %)	7 (16.3)	1 (2.3)	−†	0.058
Prolonged labor (n, %)	2 (4.7)	1 (2.3)	−†	1.000
Instrumental labor (n, %)	1 (2.3)	0	−†	1.000
Cesarean section (n, %)	21 (48.8)	16 (37.2)	1.186*	0.276
Macrosomia (n, %)	2 (4.7)	3 (7.0)	−†	1.000
Newborn weight (g, $\overline{x}\pm s$)	3112.79±420.52	3237.91±419.05	−1.382‡	0.171
Newborn body length (cm, $\overline{x}\pm s$)	49.79±1.06	49.88±0.66	−0.488‡	0.627
Neonatal BMI (kg/m^2, $\overline{x}\pm s$)	12.52±1.29	12.99±1.47	−1.582‡	0.117
Neonatal 1 min Apgar (points, $\overline{x}\pm s$)	9.84±0.75	9.72±1.18	0.544‡	0.588
Neonatal 5 min Apgar (points, $\overline{x}\pm s$)	9.95±0.21	9.93±0.34	0.382‡	0.704
Fetal distress (n, %)	1 (2.3)	0	−†	1.000
Neonatal asphyxia (n, %)	1 (2.3)	1 (2.3)	−†	1.000
Neonatal jaundice	1 (2.3)	0	−†	1.000

*χ^2 value.
†Fisher's exact test.
‡t-value.
AE, aerobic exercise; BMI, body mass index; RE, resistance exercise.

their infants, and it does not increase the incidence of adverse pregnancy outcomes such as neonatal hyperbilirubinemia, macrosomia, and cesarean section.[14 15 24–26] Previous studies have also shown that a lack of exercise during pregnancy can increase the incidence of depression, anxiety, etc,[27–29] indicating that exercise for women with GDM is safe to a certain extent and conducive to their happiness.

Compared with aerobic exercise, resistance exercise has a better effect on reducing 2-hour postprandial blood glucose level in women with GDM

The results of this study showed that both aerobic exercise and resistance exercise were helpful to reduce the average fasting and 2-hour postprandial blood glucose levels of patients with GDM (p<0.05, see table 2), and resistance exercise showed a better effect on reducing 2-hour postprandial blood glucose level (p<0.05, see table 3). There was no significant difference in the fasting blood glucose level and number of insulin users between the two groups after the intervention (p>0.05). In addition, the difference in the mean insulin use between the two groups was very small. Because only one person in each group took insulin, more samples are needed to verify the results in the future. Thus far, studies have reported relatively consistent findings on the positive effects of resistance exercise and aerobic exercise on blood glucose level and insulin use, respectively,[27 30] and the findings of the present study agreed with those of previous studies. Resistance exercise can promote skeletal muscle cells to increase the utilization and uptake of glucose, enhance glucose phosphorylation in muscle cells, promote the conversion of blood glucose to monosaccharide, maintain the insulin secretion and balance of glucose, and ultimately reduce blood glucose level.[31 32] Aerobic exercise may enhance the muscle's glucose uptake by enhancing its insulin secreting activity, thereby improving blood glucose level and insulin use.[33 34]

The effects of resistance exercise and aerobic exercise on blood glucose levels have been compared in patients with type 2 DM; however, no consistent results were obtained.[10] These differences may be related to the length of exercise intervention cycle and different forms of organizational exercise. For women with GDM, however, there are no previous studies on the effect of different forms of exercise on insulin use and blood glucose level. In the present study, the difference in the 2-hour postprandial blood glucose level between the two groups of patients after the intervention showed that resistance exercise is more effective than aerobic exercise to reduce postprandial blood sugar level. In this study, the patients underwent the exercise program at the hospital. To reduce the incidence of hypoglycemia during exercise, the patients performed exercise after meals, which may have a greater impact on postprandial blood glucose level in the two groups. This might be because in patients with GDM, the enlarged belly before labor restricts the body movement due to the fetus load.[15] This largely makes it difficult to perform aerobics; in contrast, resistance exercise through basic movements is easier to perform. Thus, the compliance of the resistance exercise group was higher than that of the aerobic exercise group, leading to the difference in results. Because the sample size of this study was small and the study was limited to only one hospital, a multicenter randomized controlled trial should be

conducted for further verification of this result. Specific resistance exercise programs can be chosen according to the physical characteristics of each individual; thus, clinical staff can develop and recommend safe and individualized specific resistance exercise programs to meet the exercise preferences and musculoskeletal limitations of patients with GDM, including intensity, timing, mode, and frequency. This may be more helpful to improve exercise compliance of pregnant women.[35]

No significant difference was observed between resistance exercise and aerobic exercise in reducing the incidence of adverse pregnancy outcomes in women with GDM

In this study, the pregnancy outcome of the two groups was compared. The results showed no difference in the effect of aerobic exercise and resistance exercise on pregnancy outcome (p>0.05, see table 4). The number of patients who underwent cesarean section in the two groups was 37, among which 20 patients had a history of cesarean section (scar uterus) before participating in the study, thus, they had to undergo cesarean section again in this delivery (the research team also chose to perform cesarean section again for pregnant women with scar uterus to reduce the risk of uterine rupture). The main reasons for cesarean section in other patients are: macrosomia occurred in five patients; two patients had prolonged labor; fetal malposition was observed in eight patients and two patients had neonatal asphyxia. Seven patients were performed for loss of fetal well-being. Two patients were emergency and 33 were scheduled. One patient underwent instrumental delivery because of prolonged labor. The number of tears in the two groups was 10, with two due to large fetal head, three due to narrow pelvic outlet, three due to perineal inflammation and two due to acute labor. Chen and Yang performed a meta-analysis to determine the effects of different forms of exercise intervention on patients with GDM, and the results showed that both aerobic exercise and resistance exercise could reduce the incidence of macrosomia and cesarean section in patients with GDM.[36] However, the study by Chen and Yang lacked a comparative investigation of the effects of the two exercise programs on adverse pregnancy outcomes in patients with GDM. The results of the present study showed that resistance exercise did not contribute more to adverse pregnancy outcomes in patients with GDM than aerobic exercise. Although the results of this study showed no significant difference in the incidence of pregnancy outcomes between the two groups, the results were based on a small sample size; hence, future multicenter studies will be beneficial to further verify the results. However, considering the physical characteristics of patients with GDM in late pregnancy and their high compliance, resistance exercise can still be promoted in the future to provide a reference for medical staff to develop a feasible exercise program. GDM pregnancy health management centers can also be established in the communities to improve the pregnancy outcome of patients with GDM. In addition, the follow-up of postpartum women and newborns can be prolonged in the future to evaluate the difference in the effect of aerobic and resistance exercise on patients with GDM after long-term intervention.

LIMITATIONS

At present, the compliance of pregnant women with GDM to exercise is still low globally; hence, it was difficult to ensure that the two groups of patients received exactly the same number of exercise interventions in this study, and further studies are required to determine whether this issue affects study results. Although the exercise intervention program was carried out only in the hospital, the researchers did not organize the exercise program again after the patients went home; therefore, it is hard to make a statistical comparison on whether the participants performed exercise autonomously after they going home. Moreover, the study was voluntary; thus, it was likely to be limited to patients who were more aware of their conditions and more willing to adhere to lifestyle changes. Moreover, many patients expressed that they did not want to undergo more invasive tests. In addition, doctors in this study did not consider the detection of insulin level and homeostasis model assessment-insulin resistance as routine examination items for patients with GDM; thus, this is a limitation that these indicators were not detected in the study patients considering that physical exercise improves insulin resistance. The research team also gave the same dietary intervention guidance to the two groups of patients. Although there was no significant difference in the nutritional compliance of the two groups of patients, the patients' compliance with dietary intervention at home was evaluated on the basis of only the self-reported data of patients during face-to-face interviews conducted in the hospital each time. This study measured the body weight of the two groups before pregnancy and at the time of diagnosis of GDM, but did not measure the body weight of all patients before delivery.

FUTURE DIRECTIONS

Postpartum follow-up studies should be conducted to further prove the long-term effects of resistance exercise and aerobic exercise intervention on mothers, and infants in the future. Early intervention in pregnant women at high risk for GDM can also be used to determine whether resistance exercise helps to prevent the development of GDM. Because of the lack of relevant studies on resistance exercise in women with GDM and the lack of a unified global guideline for GDM exercise, no research studies have been conducted to determine the best resistance exercise scheme. Therefore, detailed studies on the form, intensity, and frequency of the best type of resistance exercise should be conducted to determine effective prevention strategies and reduce national healthcare costs.

CONCLUSIONS

Resistance exercise is easier to perform, has better compliance, and is conducive to adherence during pregnancy and even in the postpartum period. It is particularly important that non-drug interventions control blood sugar levels in pregnancy, and there is a need to attend to this issue in the case of patients with GDM in the future.

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