Comparative study of circuit resistance training and aerobic training on glycemic control of gestational diabetes mellitus

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Background
Gestational diabetes mellitus (GDM) is a standout among the most well-known medical complications of pregnancy. The occurrence of GDM has multiplied in the most recent 6–8 years and is associated with the obesity epidemic.

Objective
To compare the effect of circuit resistance training (CRT) versus aerobic training (AT) on glycemic control in women with GDM.

Participants and methods
A total of 50 pregnant women with a diagnosis of GDM were randomly assigned to a CRT group or an AT group. Both the groups trained for 40 min, three times per week for 36 sessions, starting at 20–24 weeks gestation (second trimester) until the end of 37 weeks gestation. The fasting and 2-h postprandial plasma glucose levels were assessed in all the participants before and after the treatment program.

Results
The results revealed a significant decrease in both fasting and 2-h postprandial plasma glucose levels in both the groups after the training program (CRT group, $P<0.0001$ and AT group, $P<0.01$). However, the participants in the CRT group exhibited a greater decrease in both fasting and 2-h postprandial plasma glucose levels, with the mean difference between both groups being −15.05 and −46.75 mg/dl, respectively, favoring the CRT group, ($P<0.0001$).

Conclusion
These results suggest that the CRT was more effective than AT in improving glycemic control among gestational diabetic women.

Keywords:
aerobic training, circuit resistance training, gestational diabetes mellitus, glycemic control

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Introduction

Gestational diabetes mellitus (GDM) is the most common metabolic issue amid pregnancy. GDM is a standout among the most surely understood pregnancy issues; each year, ~1–14% of pregnancies are influenced by it universally. Its rate keeps on increasing alongside the expanding frequency of type 2 diabetes mellitus and excess weight [1,2]. GDM is characterized as any degree of hyperglycemia (high blood glucose) or glucose intolerance with an onset or first recognition amid pregnancy [3]. This broad definition includes women who develop glucose intolerance during gestation and those with pre-existing diabetes which was not detected before gestation. These women can be liable to hyperglycemia in the first two trimesters of gestation, resulting in an elevated incidence of cardiovascular, neurological, or musculoskeletal complications [4,5].

To diagnose GDM, it was prescribed that at least one of the accompanying plasma glucose limits ought to reached to or surpassed amid a 75-g oral glucose tolerance test: 5.1 mmol/l (fasting), 10.0 mmol/l (1 h postload), and 8.5 mmol/l (2 h postload) [6]. Two major mechanisms are responsible for stabilizing the glucose level during gestation. First, insulin resistance increases as the pregnancy proceeds, mainly during the third trimester. This insulin resistance seems to be happening because of increase in maternal weight combined with the desensitizing effects exerted on insulin by the placental hormones. Second, the β cells in the pancreas of a pregnant woman enhance their production of insulin to compensate for the increased insulin resistance. Thus, for most pregnant women, the circulating glucose levels become stable and normal despite alterations in the regulation of glucose [7]. Previous studies demonstrated that there is a relationship between body weight and GDM. Obesity is a modifiable risk factor that is strongly linked to the etiology of gestational diabetes. In a retrospective cohort study comparing 613 morbidly obese and 11,313 nonobese women who were delivered of a singleton live birth, obese ladies had a threefold higher danger of acquiring GDM than nonobese women [8]. Maternal obesity is linked to impaired glucose metabolism, as approaching pregnancy overweight or obesity is firmly related to various unfavorable pregnancy outcomes, such as the development of impaired glucose tolerance or GDM [9]. Women who are obese before pregnancy are more likely to develop impaired glucose tolerance compared with nonobese women [10]. Consequently, the American Diabetes Association has tightened the requirements for the diagnosis of GDM in women [11].

Previous studies have suggested that exercise may be used to enhance glycemic control in women with GDM and may also play a part in preventing the onset of GDM [12]. Regular exercise and a healthy diet encourage weight reduction and enhance insulin sensitivity. Exercise and weight reduction can diminish sympathetic activity, increase parasympathetic activity, and lower the resting heart rate and circulating strain. In high-risk women, enhancing insulin sensitivity and lessening overactivity with established activity and weight reduction techniques may decrease the risk of GDM [13]. Exercise has been prescribed as a safe and effective supportive therapy for the treatment of GDM, likely because skeletal muscles represent the primary site of insulin resistance observed during pregnancy. Evidence showed that aerobic exercise can decrease the frequency of insulin use among women [14]. Evidence that physical activity can enhance glucose regulation for patients with insulin dependent diabetes mellitus (IDDM) is grounded in previous studies demonstrating the glucose-lowering effect of an intense bout of exercise. This glucose-lowering effect of exercise has been replicated by many investigators [15]. Circuit training is a form of body conditioning and resistance training using high-intensity aerobics. It improves the muscular strength and endurance. An exercise 'circuit' is characterized as one fulfillment of all the recommended practices in the program. When one circuit is finished, the patient starts the first exercise again to begin the following circuit [16].

Many studies have shown that performing resistance training during pregnancy is very safe [17], and women lost weight, felt much better, and showed alleviation of many physical problems (e.g. nausea, headache, and fatigue) [18]. Further studies found that high-impact resistance combined with aerobic training (AT) is associated with diminished predominance of diabetes and hypertension amid pregnancy [19]. During pregnancy, high-impact resistance training enhances glycemic control, which additionally diminishes their need for insulin [20,21]. Preliminary studies have demonstrated that participation in intense resistance training during pregnancy is efficacious and safe for the mother and her unborn child and have no adverse on pregnancy outcomes [22–25], as it enhances the cardiorespiratory perseverance, muscle quality, lipid level, and glucose control and increases flexibility and muscle strength [26].

The circuit training program can be performed using exercise machines, flexible resistance exercises, handheld weights, or any mixture of these [27]. Circuit resistance training (CRT) has been found to be valuable in people with type 2 diabetes mellitus by improving insulin sensitivity and reinforcing antioxidant defenses; it might, likewise, diminish oxidative stress [28]. Exercise causes improved blood flow to the working muscles and also causes blood vessels to expand. Because of this combination of blood flow and vessel expansion, insulin is carried faster and more efficiently to the cells that use insulin. Thus, a burst of insulin causes the body to take up and use the sugar (glucose) in the blood; consequently, blood sugar levels begin to decrease faster than usual [29]. CRT enhances insulin function and glucose tolerance in healthy individuals, as well as in those who are obese, insulin resistant, and diabetic [30].

Consequently, the main objective of the present work was to compare the effect of CRT versus AT on glycemic control in women with GDM.

Participants and methods

Participants

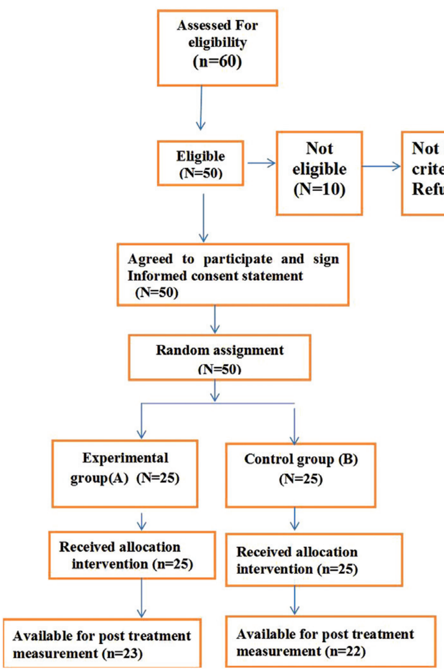
Overall, 50 female volunteers with GDM were referred to the physical therapy outpatient clinic by the obstetrician at the outpatient clinic of obstetrics at El Monira General Hospital between June and December 2014. The volunteers had similar physical activity level and were all housewives with a medium level of education (secondary school level). Their ages ranged from 25 to 30 years as the mean±SD for CRT group was 26.97±1.54 years and for AT group was 27.4±1.46 years. The BMIs were all more than 25 kg/m^2, as the mean±SD for CRT group was 32.08±1 kg/m^2 and for AT group was 31.59± 1.08 kg/m^2 and their gestational ages ranged from 20 to 24 weeks (second trimester), as the mean±SD for CRT group was 22.8±1.45 weeks and for AT group was 22.9± 1.7 weeks. Participants were screened for other pathological conditions. Exclusion criteria of the study were as follows: cardiovascular disease, chest-related diseases, pre-eclampsia, diabetes, history of antepartum hemorrhage, fetal congenital anomalies, and marked skeletal deformities. All the pregnant women accepted for this study had a normal single fetus. The gestational age of each fetus was calculated by subtracting the first day of the participant's last menstrual cycle from the date of inclusion in the study and then dividing by 7 days. The women were randomly distributed into two groups (CRT and AT) using computer-generated random numbers. The allocation was concealed in sequentially numbered opaque envelopes. We selected 50 individuals randomly into the study. No symptoms were seen in any of the participants during the treatment programs. Overall, five participants who did not agree to the treatment program were excluded from the analysis. The five participants were two from the CRT group and three from the AT group. Diagram of flow chart of the study is shown in Fig. 1.

The Ethical Committee of the Faculty of Physical Therapy at Cairo University approved this study (no.: P.T.REC/012/00893-28/4/2015). The study protocol was explained to all the women, who then signed an informed consent form.

Methods

Before the start of the first session, the treatment procedures were explained to all the women to obtain their confidence and cooperation. The pregnant women were instructed to have breakfast 1 h before each treatment session and were also asked to empty their bladder immediately before the start of each treatment session. Each exercise session was 40 min long and was held three times per week. All exercise sessions were done under the supervision of the researchers.

Figure 1



Flow chart of the study.

Circuit resistance training exercises

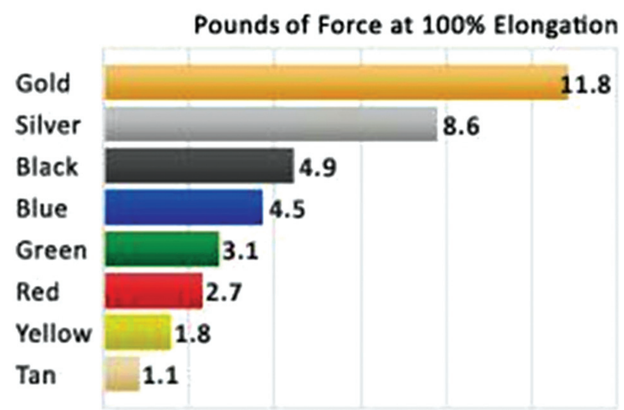
CRT group, consisting of 25 women, participated in a circuit resistance training program with two circuits, each with 10 repetitions (with 2 min rest between each circuit). The exercises were performed with green color band (during the first 4 weeks of the training program) and then blue color band (following green, until the end of 37 weeks gestation), with elastic resistance performed at 100% elongation, for 3 days/week for 36 sessions (green color=3.1 lbs and blue color=4.5 lbs) (Fig. 2) [31,32].

Muscle group exercises: the circuit resistance training program lasted for 30 min and consisted of eight exercises for the upper and lower limbs and chest muscles using an elastic band. The exercise program was designed in such a way that all the main muscle groups of the patients were exercised (chest, biceps, triceps, deltoid, quadriceps, thigh, and calf muscles). CRT was performed from a sitting position; one end of the band was fixed beneath the right foot, held for 5 s, and then released, and the exercise was then repeated on the left side and included the following exercises: chest pull, shoulder flexion, shoulder abduction, elbow flexion, elbow extension, hip abduction, knee extension, and ankle planter flexion exercise.

Aerobic exercise training program

AT group, also consisting of 25 women, participated in an AT program in the form of walking on the treadmill, for 40 min, three times per week, from 20 to 24 weeks of gestation (second trimester) until the end of 37 weeks of gestation for 36 sessions. The exercise session was divided into three stages:

Figure 2



Progressive resistance using the Theraband.

First stage (warm up): this stage consisted of 5 min of walking in place aimed to prepare the skeletal muscles, the heart, and the lungs for the acute phase of the exercise training program.

Second stage (active stage): this stage consisted of 30 min of walking on the treadmill without inclination. The participant was asked to stand on a treadmill while grasping a handle so that her heart rate appeared on a screen. The participant was then asked to walk at a steady speed of 0.7 km/h with an increase in her walking speed gradually until it reaches 60% of her maximum heart rate. The maximum heart rate of each pregnant woman was calculated by subtracting her age in years from the number 220. The heart rate was measured using a pulsometer attached to each participant's ear.

Third stage (cool down): this stage consisted of walking on the treadmill for 5 min while decreasing the speed gradually, until reaching 40% of the maximum heart rate.

Restricted diet

All the participants in both groups (CRT and AT) received a moderately restrictive diet under supervision of acertified dietician. The prescribed diet was limited to 1800–2000 Kcal/day. The participants had 10% of their calories at the breakfast, 20–30% at the lunch, 30–40% at the dinner, and 30% as snacks. The diet consisted of 40–50% low glycemic carbohydrates, 30% fat, and 20–30% protein and fibers.

Each participant was given a booklet containing a database of different types of food with their energy and macronutrient values. The dietician asked each woman to select her foods freely and gave them instructions about planning their meals to help adhere to the prescribed amount of kilocalories and the assigned macronutrients. All the participants were advised to keep 3-day dietary records and were interviewed by the therapist weekly. The dietician checked these records to ensure that the total kilocalories per day did not exceed the assigned limit and gave advice about meal planning when the participant did not consume the appropriate types of macronutrients. All the women closely adhered to the assigned energy intake.

Outcome measures

The assessment for the participants in both groups (CRT and AT) was carried out before and after the treatment program by collecting fasting plasma glucose levels and 2-h postprandial plasma glucose levels.

The 2-h postprandial plasma glucose test is a blood test that determines the plasma glucose levels exactly 2 h following a meal containing a set amount of carbohydrate. The 2-h postprandial plasma glucose tests show how tolerant the body is to glucose.

Sample size determination

The minimum sample size needed for 80% statistical power and at 5% significance level was 22 for every group. Estimated power for 50 patients had been calculated as 90.7% [33].

Statistical analysis

The collected data were statistically analyzed using an unpaired *t*-test to compare between the mean values of different variables between the two groups. Paired *t*-tests were used to compare variations within the same group. The statistical package for the social sciences computer program (Windows Version 16; SPSS Inc., Chicago, Illinois, USA) was used for data analysis. Data were presented as mean and SD, and the percentage of change was estimated. Data were considered to be significant at P value less than 0.05 and highly significant at the P less than 0.001.

Results

Table 1 showed that there was no significant difference between the mean age, BMI, and gestational age of the two groups (CRT and AT) at the beginning of the study, as P is equal to 0.316, 0.103, and 0.824, respectively.

Blood glucose level of the participants

At the beginning of the study, before starting of the treatment program, there was no significant difference in both the mean fasting and 2-h postprandial plasma glucose level between both the CRT and AT groups, as

Table 1 General characteristics of the participants

General characteristics	CRT group (n=25) (mean±SD)	AT group B (n=25) (mean±SD)	Comparison			Significance
			MD	t-Value	P-value	
Age (years)	26.97±1.54	27.4±1.46	−0.43	−1.013	0.316	NS
BMI (kg/m^2)	32.08±1	31.59±1.08	0.49	1.665	0.103	NS
Gestational age (years)	22.8±1.45	22.9±1.7	−0.1	0.224	0.824	NS

AT, aerobic training; CRT, circuit resistance training; MD, mean difference; *t*-value, unpaired *t*-value.

P is equal to 0.887 and 0.350, respectively, as shown in Table 2.

After the end of the treatment program, regarding the CRT group (Table 3), after the end of the CRT program, there was a highly statistically significant decrease in both the mean fasting and 2-h postprandial plasma glucose level (with $P<0.0001$), and the percentage of change was 21.53 and 33.14%, respectively.

Regarding the AT group (Table3), after the end of the AT program, there was a statistically significant decrease in both the mean fasting and 2-h postprandial plasma glucose level (with $P<0.01$), and the percentage of change was 5.46 and 4.39%, respectively.

On comparison between the post-treatment mean values of blood glucose level for both CRT and AT groups, after the end of the treatment program, there was a highly statistically significant decrease in both fasting and 2-h postprandial plasma glucose levels of the CRT group compared with AT group, as the mean difference values between both groups were −15.05 and −46.75 mg/dl, respectively, favoring the CRT group, with *P* less than 0.0001, as shown in Table4.

Discussion

According to the statistical analysis of the result of the study, it was found that the CRT program is more effective than AT for women with GDM, as demonstrated by a significant reduction in both the fasting and 2 h postprandial plasma glucose levels ($P<0.0001$) compared with AT after 3 months of treatment. These results are in accordance with those of de Barros *et al.* [20]. In their study, the resistance training program was able to successfully reduce the number of patients with GDM and enhance the capillary glycemic control of the participants. Likewise, a similar study by the American Diabetes Association [34] investigated the effect of mixed endurance and strength activities on adolescents having IDDM performing the circuit training. The participants performed these exercises three times weekly, for 12 weeks. This program resulted in a significant improvement in the muscle power, cardiorespiratory endurance, lipid level, and glucose control of the participants. The study authors concluded that circuit training is extremely safe for well-trained and monitored adolescent diabetics. Besides, the current results are in accordance with those of Artal *et al.* [35] and Poehlman *et al.* [36] who showed that exercise and caloric restriction resulted in a limited weight gain in obese patients with GDM, with less macrosomic infants and no adverse pregnancy adverse effects.

Additionally, a randomized clinical control trial conducted by Jovanovic-Peterson *et al.* [37] showed that a 6-week arm ergometry exercise program normalized the fasting and 1-h plasma glucose levels and glycosylated hemoglobin (HbA1c) in women with

Table 2 Comparison between pretreatment mean values of the blood glucose level of both circuit resistance training and aerobic training groups

Plasma glucose level (mg/dl)	CRT group (*n*=25) (20–24 weeks gestation) (mean±SD)	AT group (*n*=25) (20–24 weeks gestation) (mean±SD)	MD	*t*-Value	*P*-value	Significance
Fasting	91±11.23	91.45±10.95	−0.45	−0.143	0.887	NS
Two-hour postprandial	172.6±10.53	169.6±11.92	3	0.943	0.350	NS

AT, aerobic training; CRT, circuit resistance training; MD, mean difference; *t*-value, paired *t*-value.

Table 3 Comparison between pretreatment and post-treatment mean values of the blood glucose level of both circuit resistance training and aerobic training groups

Plasma glucose level (mg/dl)	CRT group (*n*=23) (37 weeks gestation)		AT group (*n*=22) (37 weeks gestation)	
	Fasting	Two-hour postprandial	Fasting	Two-h postprandial
Before treatment (20–24 weeks gestation) (mean±SD)	91±11.22	172.6±10.52	91.45±10.94	169.6±11.93
After treatment (37 weeks gestation) (mean±SD)	71.4±11.08	115.4±17.18	86.45±8.77	162.15±16.11
MD	19.6	57.2	5	7.45
% of change	21.53	33.14	5.46	4.39
t-Value	6.79	11.37	2.71	2.57
P-value	0.0001	0.0001	0.01	0.01
Significance	HS	HS	S	S

AT, aerobic training; CRT, circuit resistance training; HS, highly significant; MD, mean difference; S, significant; *t*-value, unpaired *t*-value.

Table 4 Comparison between the post-treatment mean values of the blood glucose level between circuit resistance training and aerobic training groups

Plasma glucose level (mg/dl)	CRT group (*n*=23) (37 weeks gestation) (mean±SD)	AT group (*n*=22) (37 weeks gestation) (mean±SD)	MD	*t*-Value	*P*-value	Significance
Fasting	71.4±11.08	86.45±8.77	−15.05	−5.325	0.0001	S
Two-hour postprandial	115.4±17.18	162.15±16.11	−46.75	−9.925	0.0001	S

AT, aerobic training; CRT, circuit resistance training; MD, mean difference; S, Significant; *t*-value, unpaired *t*-value.

GDM who had been randomized to dieting plus exercise compared with dieting only.

Dunstan *et al.* [38] assessed the effect of short-term CRT on glycemic control in participants with non insulin dependent diabetes mellitus (NIDDM). A total of 27 inactive patients with NIDDM underwent exercise training program for a 8-week randomized, controlled study. The participants were either tasked with a CRT program 3 days/week (n=15) or no formal activity (control) (n=12). The study authors concluded that short-term CRT results in a significant reduction in both fasting plasma insulin and glucose levels; therefore, CRT is considered to be a valuable alternative exercise in the daily lifestyle of these individuals.

In addition, Shabani *et al.* [39] reported that the CRT done 3 days/week for 3 months experienced a positive effect on glycemic control in women diagnosed as having diabetes type II, with substantial alterations in HbA1c and reduction of subcutaneous fat being recorded in the CRT group.

Moreover, another study evaluated the resistance training and AT in women around 40 and 70 years of age in two groups. They showed change in HbA1c following 4 months in both groups [40].

Another study demonstrated that 12 weeks of progressive, moderate-intensity resistance exercise training program brought about critical changes in glycemia in Indians with type II diabetes [41,42]. Dunstan *et al.* [43] inferred that high-intensity, dynamic resistance preparing, in mix with direct weight reduction, was compelling in enhancing glycemic control in older patients with type 2 diabetes. The additional advantages of enhanced muscular power and lean body mass identify that high-volume resistance preparing as a viable and powerful part in the treatment program for elder patients having type 2 diabetes.Cuff *et al.* [44] and Barbour *et al.* [45] reported that performing resistance training in combination with aerobic exercises program improved glucose transfer in postmenopausal women with type 2 diabetes. The enhanced insulin sensitivity is associated with reduction of visceral adiposity and abdominal subcutaneous and to expanded density of muscle.

Several findings were additionally recorded by Castenada *et al.* [46] who randomized 62 older patients to either high-intensity progressive resistance training group or a nonexercising control group for continuous 4 months. It resulted in diminished plasma glycosylated hemoglobin levels (from 8.7±0.3 to 7.6±0.2%), enhanced muscle glycogen stores (from 60.3±3.9 to 79.1±5.0 mmol glucose/kg muscle), and diminished need of diabetes medication among 72% of exercising patients in contrast with the control group, as addition of exercising to standard of care is attainable and extremely successful in enhancing glycemic control.

The molecular mechanisms that mediate the enhanced insulin sensitivity and clearance of the glucose after exercising are identified with the increased expression and activity of signaling enzymes and proteins that are included in the fat metabolism and skeletal muscle glucose [47].

However, all the previous studies that have evaluated the effect of resistance training on the glycemic control in patients with type 2 diabetes and elderly patients with type 2 diabetes, none have investigated which is best for gestational diabetes.

In all of these previous studies, the resistance training time was limited to short duration (i.e. <8 weeks), in contrast to 12 weeks of circuit resistance training program used in our study. The women were advised at home to change the way of eating, exercising regularly, and checking the blood sugar.

Conclusion

The CRT program resulted in improved glycemic control in women with GDM, as demonstrated by improved blood plasma glucose levels in the participants. Therefore, CRT is a very effective and safe intervention to improve glycemic control and reduce plasma glucose levels in pregnant women with GDM.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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