Effect of Aerobic Exercise on Maternal Hyperglycemia and Fetal Macrosomia in Diabetic Pregnant Women

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ABSTRACT

This study was conducted to determine the effect of moderate intensity aerobic exercise on maternal hyperglycemia and fetal macrosomia in diabetic pregnant women. Fifty pregnant women, who had gestational diabetes mellitus (GDM), their age were ranged between 25-35 years and their gestational age were ranged between 20 and 24 weeks, participated in this study. They were divided randomly into two groups equal in number (A&B). The patients in the study group (A) received moderate intensity aerobic exercise program in addition to moderate restricted diet (1800-2000 Kcal.) while, patients in the control group (B) were treated by diet therapy in the form of moderate restricted diet (1800-2000 Kcal.) only. All cases in both groups (A&B) were evaluated through 3 hours oral glucose tolerance test at the start and the end of the study. Neonatal birth weight was measured immediately after delivery for both groups. The results of this study revealed that aerobic exercise in the form of walking on treadmill, at moderate intensity (60-75 % of maximum heart rate), for 45 minutes, 3 times/ week, 1 hour after the main meal and insulin injection, from 20-24 weeks' gestation till delivery, in diabetic pregnant women, together with diet therapy (1800-2000 kcal/day), decreased the blood glucose level and hyperglycemia compared with diet alone. In the study group fasting blood glucose level reduced by 32.58% , 1 hour BGL reduced by 14.35 %, 2 hours BGL reduced by 26.73% and 3 hours BGL reduced by 36,10% after treatment. The new born birth weight in the study group is less than those in the control group by 29.5%, so, it could be concluded that aerobic exercise in conjunction with diet therapy had a great effect in reducing maternal hyperglycemia and fetal macrosomia in diabetic pregnant women.

Key words: *Gestational diabetes, Pregnancy, Aerobic exercise, Moderate intensity, Blood glucose level, Fetal macrosomia, Oral glucose tolerance test.*

INTRODUCTION

Diabetes mellitus is a group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both. The chronic hyperglycemia of diabetes is associated with long-term damage, dysfunction, and failure of various organs, especially the eyes, kidneys, nerves, heart and blood vessels[13].

Several pathogenic processes are involved in the development of diabetes. These range from autoimmune destruction of ß-cells of the pancreas with consequent insulin deficiency to abnormalities that result in resistance to insulin action. The basis of the abnormalities in carbohydrate, fat, and protein metabolism in diabetes is deficient action of insulin on target tissues. Deficient insulin action results from inadequate insulin secretion and/or diminished tissue responses to insulin at one or more points in the complex pathways of hormone action. Impairment of insulin secretion and defects in insulin action frequently coexist in the same patient, and it is often unclear which abnormality, if either alone, is the primary cause of the hyperglycemia[38].

Although the mechanisms responsible for ß-cell destruction are poorly understood, disturbances in the physiology of the gut-derived incretins have been suggested. Incretins are two gastrointestinal hormones, gastric inhibitory polypeptide (GIP) and glucagon-like peptide-1 (GLP-1), which enhance the secretion of insulin to a greater degree after the oral administration of glucose compared with the amount of insulin secreted when a similar level of hyperglycemia is achieved with intravenous glucose. Once diabetes develops, GLP-1 secretion is reduced, and ß-cells are resistant to the effects of GIP[37].

Pregnancy is a diabetogenic condition characterized by insulin resistance with a compensatory increase in ß-cell response and hyperinsulinemia[29]. The placental secretion of hormones (progesterone, cortisol, placental lactogen, prolactin, and growth hormone) is a major contributor to the insulin resistance, which likely plays a role in ensuring that the fetus has an adequate supply of glucose[11].

Pregnancy in patients with diabetes is associated with an increased incidence of congenital anomalies for the fetus and spontaneous abortions in women with poor glycemic control[34]. The effect of the increased glucose levels on the rate of spontaneous abortion occurs at the time of conception. Normalizing blood glucose concentrations before and early in pregnancy can reduce these risks to levels of the general population[28].

Gestational diabetes mellitus (GDM) is a common medical problem that results from an increased severity of insulin resistance as well as an impairment of the compensatory increase in insulin secretion[36].

Gestational diabetes mellitus is defined as any degree of glucose intolerance with onset or first recognition occurs during pregnancy. It is characterized by glucose intolerance associated with fetal macrosomia, which contributes to the increased maternal and fetal morbidity. The definition applies regardless of whether insulin or only diet modification is used for treatment or whether the condition persists after pregnancy. It does not exclude the possibility that unrecognized glucose intolerance may have antedated or begun concomitantly with the pregnancy[35].

According to diagnostic criteria that recommended by the American Diabetes Association (ADA), GDM is diagnosed if two or more blood glucose levels meet or exceed the following thresholds: fasting glucose concentration of 95 mg/dl, 1-hour glucose concentration of 180 mg/dl, 2-hours glucose concentration of 155 mg/dl, or 3-hours glucose concentration of 140 mg/dl[9].

In Gestational diabetes mellitus, placental hormones block the normal action of insulin in the body during pregnancy causing a problem which is called insulin resistance. Insulin resistance makes it hard for the mother to use insulin, so, she may need up to three times as much insulin as when she was not pregnant[24].

Gestational diabetes mellitus (GDM) affecting ~7% of all pregnancies. The detection of GDM is important because of its associated maternal and fetal complications. Treatment with medical nutrition therapy, exercise, close monitoring of glucose levels, and insulin therapy if needed can help to reduce these complications[30].

GDM may result in many complications during pregnancy; these complications include congenital anomalies, miscarriage, pre-eclampsia, polyhydramnios, iatrogenic preterm delivery and infection. The negative consequences that diabetes may have on a fetus are macrosomia, respiratory distress syndrome (RDS), hypoglycemia, and hyperbilirubinemia[33].

Macrosomia, defined as birth weight > 4,000 gm., occurs in infants whose mothers have GDM. Maternal factors associated with an increased incidence of macrosomia include hyperglycemia, high body mass index (BMI), older age and multiparity[11]. Macrosomia makes delivery more difficult and thus, can lead to increased rates of cesarean sections or shoulder dystocias during vaginal deliveries. Achieving maternal euglycemia is so important in avoiding fetal complications and macrosomia[19].

The goal of nutrition therapy for women with gestational diabetes is to promote nutrition necessary for maternal and fetal health, with adequate energy levels for appropriate gestational weight gain, achievement and maintenance of normoglycemia, and absence of ketones. Carbohydrate is distributed throughout the day among three small-to-moderate-size meals and two to four snacks. An evening snack may be needed to prevent accelerated ketosis overnight. Specific nutrition/food recommendations are determined and modified based on individual assessment and self-blood glucose monitoring data[4].

Several researches have focused on the use of energy-restricted diets during pregnancy. Hypo-caloric diets (<1,200 kcal/day) in obese women with gestational diabetes have been shown to result in ketonemia and ketonuria[21]. In one study, a modest energy reduction (33% calorie restriction of estimated energy needs or ~ 1,600–1,800 kcal/day) resulted in reduced mean blood glucose levels without elevations in plasma free fatty acids or ketonuria whereas, a more severe energy reduction (50% calorie restriction) increased ketonuria by about twofold[20].

Exercise leads to diverse adaptations that have significant impact on glucoregulation, even after the cessation of exercise. These adaptations largely share the common purpose of replenishing fuel stores, particularly muscle and liver glycogen[23]. So, the American colleague of obstetrics and gynecologists recommends that pregnant women have to perform some forms of moderate exercise daily[22].

In sedentary women who decide to exercise during pregnancy, ACOG (2001) (4) recommends that exercise heart rates should not exceed 140 b/m (~ 40-60% of VO_{2max}), Each exercise session should begin with a 5- to 10-minutes warming-up involving some flexibility exercises (stretching) to reduce the risk of musculoskeletal injury during the workout, and ended with a cool-down period for readjustment of H.R to the pre-exercise level[5].

Minimum of three episodes of exercise per week, each >15 mins, is required to modify maternal glucose levels. In addition, more than 6 weeks of regular exercise may be required before a lowering of glycemia is seen[3].

To improve glycemic control, assist with weight maintenance, and reduce risk of CVD, Sigal et al. (2005)[31] recommended at least 150 mins/week of moderate-intensity aerobic physical activity (40-60% of VO_{2max} or 50-75% of maximum heart rate) and/or at least 90 mins/week of vigorous aerobic exercise.

The recommended forms of exercise include walking, stationary bicycling, low-impact aerobics, and swimming[2]. Each exercise session should begin with a 5 to 10 minutes warm-up period involving some flexibility exercises (stretching) to reduce the risk of musculoskeletal injury during the workout, and ended with a cool-down period. In sedentary women who decide to exercise during pregnancy, ACOG recommends that exercise heart rates should not exceed 140 b/min (~ 60-75 % of VO_{2max})[7].

Numerous metabolic and homodynamic factors may contribute to the improvements in glucose homeostasis that are seen after exercise training in individuals with insulin resistance. These adaptive responses include enhanced insulin action on the skeletal muscle glucose transport system, reduced hormonal stimulation of hepatic glucose production, improved blood flow to skeletal muscle, and normalization of an abnormal blood lipid profile[16].

During exercise, whole-body oxygen consumption may increase by about 20-fold, and even greater increases may occur in the working muscles. To meet its energy needs under these circumstances, skeletal muscle uses, at a greatly increased rate, its own stores of glycogen and triglycerides, as well as free fatty acids (FFAs) derived from the breakdown of adipose tissue, triglycerides and glucose released from the liver. To preserve central nervous system function, blood glucose levels are remarkably well maintained during exercise and hypoglycemia during exercise rarely occurs in nondiabetic individuals. The metabolic adjustments that preserve normoglycemia during exercise are mainly hormonally mediated[10].

This study was designed to find out if aerobic exercise can be considered as a method of treatment which can help in reducing maternal hyperglycemia and fetal macrosomia in diabetic pregnant women.

SUBJECTS, MATERIALS AND METHODS

1- Subjects

Fifty diabetic pregnant women between 20-24 weeks' gestation, suffering from GDM were selected from Obstetrics Outpatient Clinic and Inpatient Department at Kasr El-ainy University Hospital. Their age was ranged from 25 to 35 years. They had no vascular complications, unstable diabetes, peripheral neuropathy, autonomic dysfunction, nephropathy or retinopathy. Each patient participated in this study had no pre-eclampsia, history of ante-partum hemorrhage or history of pre term labour. All patients were under insulin therapy and had normal counter regulatory mechanisms to counteract hypoglycemia. An informed consent form had been signed from each patient before starting the study, then the patients were divided randomly into two equal groups (A & B).

Group A (study group):

Twenty five pregnant diabetic women, their age ranged from 25 to 34 yrs, with a mean value of 28.500 ± 2.626 yrs and gestational age between 20 & 24 weeks, with a mean value of 21.000 ± 1.522 weeks. Their BMI ranged from 26.10 to 37.14 Kg/m^2 with a mean value of 31.560 ± 2.415 Kg/m^2 and all of them were under insulin therapy. Patients of this group received moderate restricted diet (1800 – 2000 kcal. / day) in addition to aerobic exercise in the form of walking on the treadmill at 0 grade, intensity between 60 % & 75% of the maximum heart rate, for 45 minutes every other day till delivery.

Group B (control group):

Twenty five pregnant women, their age ranged from 25 to 35 yrs, with a mean value of 27.850 ± 3.329 yrs, their gestational age between 20 and 24 weeks with a mean value of 21.350 ± 1.531 weeks. Their BMI ranged from 26.44 to 38.49 Kg/m^2 with a mean of 31.316 ± 3.257 Kg/m^2 and all of them were under insulin therapy. They received moderate restricted diet (1800 – 2000 kcal. / day) together with their insulin therapy till delivery.

For both groups, three hours oral glucose tolerance test was done before starting the treatment and at 37 weeks' gestation while newborn birth weight was measured immediately after delivery.

The physical characteristics and 3- hours oral glucose tolerance test before the treatment for both groups (A&B) are summarized in table (1).

Table (1): Statistical summary of the physical characteristics and 3- hours oral glucose tolerance test before the treatment for both groups (A&B).

	Study group (A)	Control group (B)	t-value	P-value	Significance
Age (yrs)	28.50±2.62	27.85±3.32	0.686	0.497	N.S
Weight (kgs)	83.24±5.19	80.54±6.20	1.491	0.144	N.S
Height (cms)	162.55±4.54	160.61±4.60	1.342	0.188	N.S
BMI (kg/m2)	31.56±2.45	31.31±3.25	0.268	0.791	N.S
GA (weeks)	21.00±1.52	21.35±1.53	-0.725	0.473	N.S
Fasting blood glucose	140.25±54.53	141.75±64.17	0.071	0.932	N.S
1 hour blood glucose	247.45±52.18	241.05±47.34	0.406	0.687	N.S
2 hours blood glucose	279.60±72.26	266.90±67.91	0.573	0.570	N.S
3 hours blood glucose	276.00±72.87	240.35±54.45	0.852	0.081	N.S

2. Instrumentations

A) For evaluation:

- Recording data sheet: All information of each patient participated in this study were recorded in a recording sheet.
- Three hours glucose tolerance test was done to measure blood glucose level.
- Weight-height scale was used to measure body weight and height for each subject for calculating her body mass index.
- Weight scale for measuring the newborn birth weight.
- A mercury sphygmomanometer and a stethoscope were used to measure blood pressure level to exclude hypo- or hypertensive patients.
- Blood glucose monitor device, Accu-chek active, SPV-446, was used for checking blood glucose level prior to and after each treatment session to detect the presence of post-exercise hypoglycemia.

B) For treatment:

- Treadmill (Power 220-V., 50/60 Hz): was used for training of the patients of group (A).
- Plinth: was used for positioning the patient in a comfortable relaxed position during measuring of blood pressure prior to each treatment session, and during stretching of major muscle groups in both lower limbs as a warming up.
- Stop watch: was used for adjusting the duration of warming up and cooling down for patients of group (A).

3. Procedures

A) For Evaluation:

- Subjective Evaluation: The initial evaluation for all cases in both groups (A&B), included obstetric history, diabetic history, the insulin dosage, and any prescribed medical treatment were recorded before starting the treatment.
- Objective Evaluation: For all cases in both groups (A&B) in the form of three hours glucose tolerance test had been done at the start of the study and at 37 weeks' gestation.

All of diabetic pregnant women at the start of this study had undergone three-hours 100-gm. OGTT (100-gm. oral glucose load administered in a fasting state). Biochemical analyses of blood were performed on fresh samples in a core laboratory facility. The test was performed in the morning after a 12 to 14 hours fasting. Blood glucose values were measured while fasting and every hour for three hours after the ingestion of 100 gm. of glucose. And this test was repeated at 37 weeks' gestation for each woman in this study.

- The maximum heart rate was determined for each subject.

  Maximum heart rate =220 – Age.
- The heart rate was measured before starting the treatment session and throughout every session.
- Blood pressure was measured before starting every session and the session was being cancelled if the patient was hyper- or hypo-tensive.
- Immediately after delivery, for all cases the newborn birth weight was measured.

B) For Treatment:

All patients in both groups (A & B) were instructed about their diet which was a moderate restricted diet limited to 1800 – 2000 kcal. / day.

Diet Formation

1- Diet of all subjects in both groups (study and control) was limited to 1800-2000 kcal/day. Distribution of calories during the day was 10% of calories at breakfast, 20% to 30% of calories at lunch, 30% to 40% of calories at supper, and 30% of calories as snacks.

2- The diet contained:

- 40%-50% Low glycemic carbohydrate: As postprandial glucose concentrations are mainly dependants on the carbohydrate content of the last meal. So the carbohydrate content of the diet in a diabetic pregnant woman should be less than in the prepregnant state.
- 30% fat: Decreasing the carbohydrate content of the diet results in increased fat intake.
- 20%-30% protein.
- Fibers: Consumption of foods high in soluble fibers, like: fruit, beans, and oat bran should be encouraged. As soluble fibers form gels that delay the absorption of carbohydrate from the gastrointestinal tract.

Treatment sessions

Before starting the first session, the treatment procedure was explained to each diabetic pregnant woman to increase her interest and motivation as well as, to obtain her confidence and cooperation.

The woman was instructed to receive her insulin therapy and her breakfast 1 hour prior to the treatment session to avoid hypoglycemia, and it is preferable for insulin to be taken in the abdomen and not injected into active muscles (extremities). Women taught to palpate their uterus during exercise to detect contractions and to discontinue the exercise if contractions occurred.

1- Warming up:

The warm-up was done to prepare the skeletal muscles, heart, and lungs for a progressive increase in the work load. Total warming up period was 10 minutes in the form of stretching the major muscle groups of both lower limbs (5mins.) and walking in place (5 mins.).

2- Active period:

In form of 30 mins. walking on a treadmill (0 grade) at 60-75% of the maximum heart rate for each patient in group (A). The active period was started by standing of the woman on the treadmill and catching the handles by her hands, so her pulse rate appeared on the screen of the machine. She was asked to maintain standing for 1 minute then we picked the heart rate from the screen. She was asked to start walking with the speed of the machine adjusted at 0.8 km./hour, so her resting pulse rate were increasing, then we increased the speed by 0.2 km./hour gradually every 2 minutes (to give a time for adjustment of the heart rate) till reaching target heart rate (60-75% of maximum heart rate).

3- Cooling down:

Cool-down was performed immediately after the active period, in the form of walking at low intensity (40% of the maximum heart rate) on treadmill for 5 mins. in order to gradually bring the heart rate to its pre-exercise level.

4- statistical analysis:

- The data were coded and entered on an IBM compatible computer using the statistical package SPSS VII.
- The mean and standard deviation were calculated for each variable, for both study and control groups before and after the application of treatment program.
- Independent t-test was done to compare the pre and post-treatment results for the study group with the control group.
- Percentage of change for each variable in both study and control groups was calculated by using: Mann-Whitney test[29].

RESULTS

For the study group (A), the three hours glucose tolerance tests showed a highly significant (P<0.001) decrease as a response to the treatment program. The percentages of change were 32.58%, 14.35%, 26.73% and 36.10% in the fasting, 1hour, 2 hours and 3 hours post prandial blood glucose levels respectively after the treatment program as shown in table (2) and fig. (1).

Table (2): Statistical summary of 3- hours oral glucose tolerance test before and after treatment program for group (A).

	Before ttt	After ttt	% 0f change	P-value	Significance
Fasting blood glucose	140.25±54.53	94.55±15.10	32.58% ↓	< 0.001	H.S
1 hour blood glucose	247.45±52.18	211.95±57.25	14.35% ↓	< 0.01	H.S
2 hours blood glucose	279.60±72.26	204.85±66.48	26.73% ↓	< 0.001	H.S
3 hours blood glucose	276.00±72.87	176.35±56.08	36.10% ↓	< 0.001	H.S

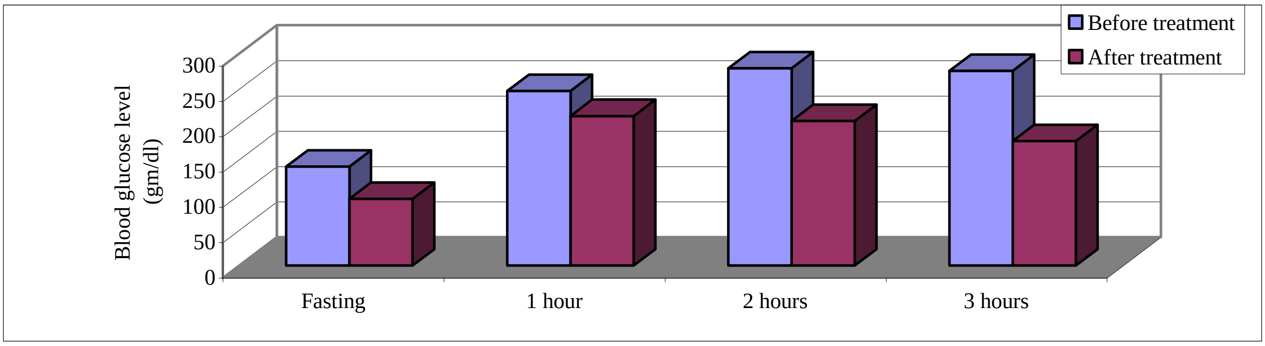

Fig. (1): 3- hours oral glucose tolerance test before and after treatment program for group (A).

In the control group (B), the three hours glucose tolerance tests showed a significant (P<0.01) increase after the treatment program and the percentages of change were 6.11% and 4.48% in the fasting and 1hour post prandial blood glucose level, while it showed a highly significant (P<0.001) increase with percentages of change equal 8.30% and 35.57% in the 2hours and 3hours post prandial blood glucose levels respectively as shown in table (3) and fig. (2).

Table (3): Statistical summary of 3- hours oral glucose tolerance test before and after treatment program for group (B).

	Before ttt	After ttt	% 0f change	P-value	Significance
Fasting blood glucose	141.75±64.17	150.95±68.07	6.11% ↑	0.028	S
1 hour blood glucose	241.05±47.34	251.85±51.29	4.48% ↑	0.034	S
2 hours blood glucose	266.90±67.91	289.05±76.41	8.30% ↑	< 0.01	H.S
3 hours blood glucose	240.35±54.45	325.85±73.64	35.57% ↑	< 0.001	H.S

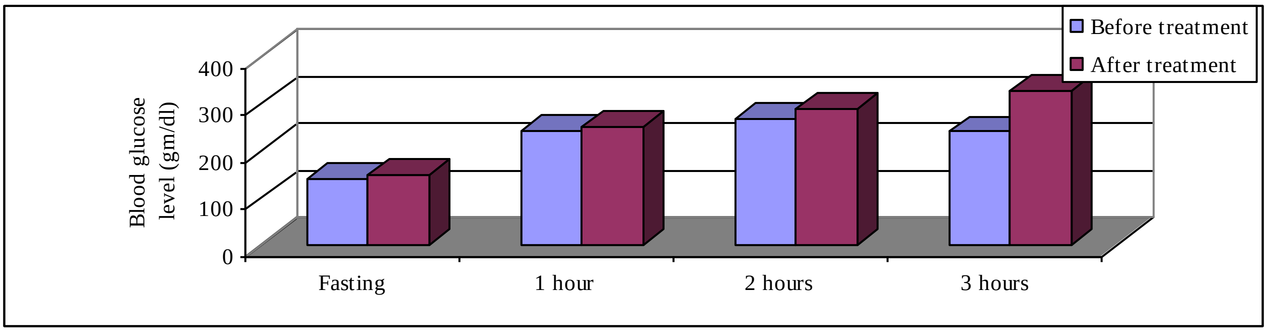

Fig. (2): 3- hours oral glucose tolerance test before and after treatment program for group (B).

When comparing the results of the three hours glucose tolerance test after the treatment program for both groups (A&B), it was found that there were a highly significant (P< 0.001) decrease in fasting, 2 hours post prandial and three hours post prandial blood glucose level in group (A) than group (B), while there was a significant decrease in 1 hour post prandial blood glucose level in the study group (A) than the control group (B) as shown in table (4) and fig. (3).

Table (4): Statistical summary of 3- hours oral glucose tolerance test after the treatment for both groups (A&B).

	Study group (A)	Control group (B)	t-value	P-value	Significance
Fasting blood glucose	94.55±15.10	150.95±68.07	-3.470	< 0.001	H.S
1 hour blood glucose	211.95±57.25	251.85±51.29	-2.321	< 0.026	S
2 hours blood glucose	204.85±66.48	289.05±76.41	-3.718	< 0.001	H.S
3 hours blood glucose	176.35±56.08	325.85±73.64	-8.691	< 0.001	H.S

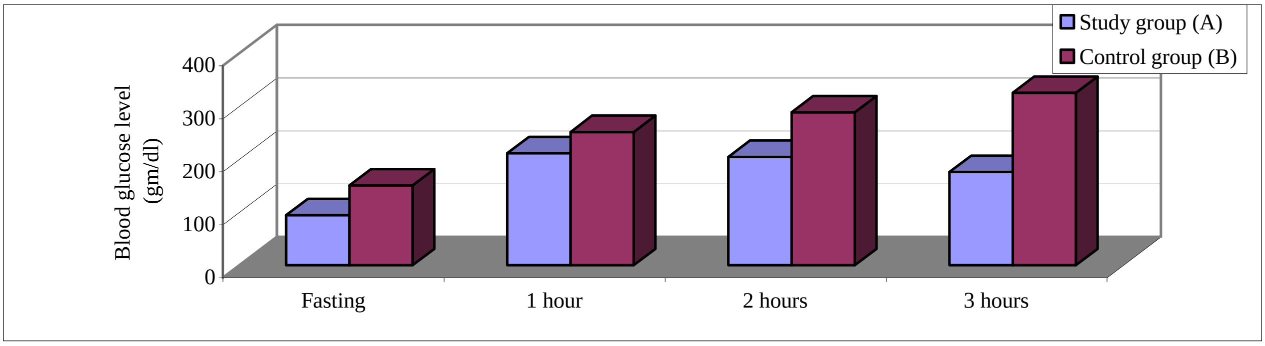

Fig. (3): 3- hours oral glucose tolerance test after the treatment program for both groups (A&B).

The new born birth weights were measured immediately after delivery for both groups (A&B) to assess the effect of moderate intensity exercise on fetal macrosomia and it was found that there was a highly significant (P<0.001) decrease in birth weights of new born infants of the study group (A) than those of the control group (B) as shown in table (5) and fig.(4).

Table (5): New born birth weight immediately after delivery for both groups (A&B).

New born birth weight	Study Group (A)	Control Group (B)	t-test	
			t	P-value
Range	3.10-5.60	3.25-5.90	4.43	<0.001
Mean	3.62	5.13		
±SD	0.83	0.85		

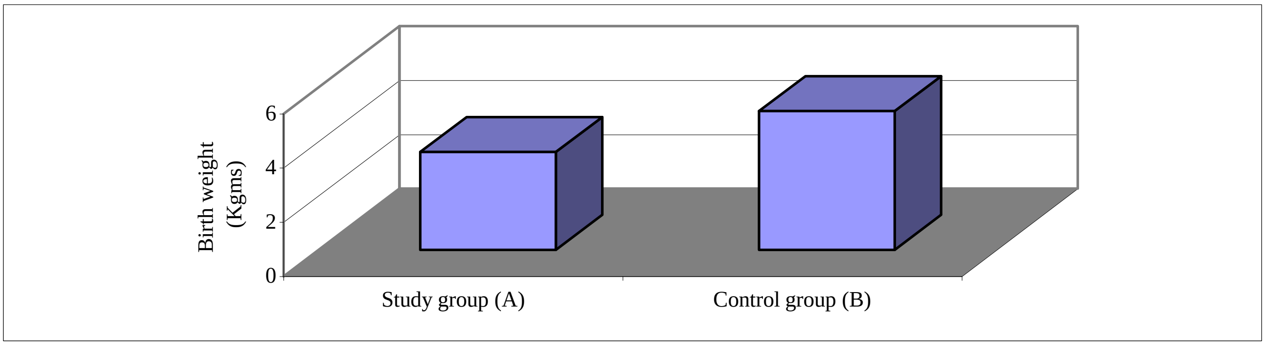

Fig. (4): New born birth weight immediately after delivery for both groups (A&B).

DISCUSSION

Diabetes may result in many complications during pregnancy; these complications include congenital anomalies, miscarriage, pre-eclampsia, polyhydramnios, iatrogenic preterm delivery, infection, an increased risk of cesarean delivery and neonatal problems, such as macrosomia, hypoglycemia, hyperbilirubinemia, polycythemia, hypocalcemia, perinatal mortality, and respiratory distress syndrome[33].

Gestational diabetes develops when there is insufficient maternal pancreatic reserve to compensate for the diabetogenic forces of pregnancy. The fetus responds to the hyperglycemia by secreting large quantities of insulin. The result is increasing adiposity and visceral fat that eventually results in decreased fetal pancreatic reserve and the infant is at risk for developing subsequent diabetes. Thus, hyperglycemia begets hyperglycemia[14].

On basis of literature review, there is not enough information to assess whether aerobic exercise is useful for pregnant women with diabetes; little information is available in the literature regarding the effect of aerobic exercise on maternal blood glucose level or on new born birth weight. The only information available is derived from studies conducted on rats.

It was originally hypothesized that aerobic exercise (endurance training) would improve maternal hyperglycemia due to improvement in glucose tolerance. The physiological basis underlying our hypothesis is derived from several lines of evidence. First, aerobic exercise may reduce insulin resistance which is absolutely high in GDM[30]. Second, it may increase insulin sensitivity[27], as higher levels of insulin sensitivity are associated with improved metabolic profile. Third, endurance training may preferentially improve glucose effectiveness[25].

In agreement with the reduction of maternal hyperglycemia obtained in this study, Nishida et al. (2004)[26] approved that 12-weeks' exercise training at moderate intensity significantly increased both the peripheral glucose effectiveness and insulin sensitivity. These results suggested that moderate exercise training improves not only insulin-dependent glucose uptake but also, insulin-independent glucose uptake (glucose-dependent) in healthy humans, so decrease plasma glucose level.

Although it has been suggested that exercise training leads to a reduction in body fat as a prerequisite to improve glucose disposal[17]. Also, Poehlman et al. (2000)[27] approved that, endurance training improved insulin sensitivity to a greater degree than resistance training, and they approved that a program of endurance training improves glucose disposal independent of a reduction in total and regional body fat in non obese young women.

In agreement with the results of our study, there are several short-term studies that have demonstrated improvement in insulin sensitivity in diabetic patients with 2–12 months of dietary changes and exercise[1].

García-Patterson et al. (2001)[14], in a study conducted on pregnant women had GDM by single bout of exercise, they founded that there was significant difference in 1 hour postprandial blood glucose level (BGL) which supports our results, but they founded no significant difference in fasting or 2 hours post prandial BGL which disagree with our results in fasting and 2 hours post prandial BGL. This may be due to limited duration of the treatment in their study, but they concluded that in addition to the benefits of physical training on blood glucose control, women with GD could benefit from postprandial exercise and potentially avoid or delay insulin therapy. In our study, all cases in the study group gradually decreased the insulin dosage throughout pregnancy with continuation of exercise till reached minimal doses but no one has stopped it completely.

Simpson and Kast (2000)[32], suggested that women with GDM are comparable to those without GDM when 2-hours postprandial glucose levels are maintained up to 144 mg/dl, which comes in agreement and supported our results. In this study, there was a significant difference between group (A) and group (B) in the 2-hour post-prandial glucose levels. 2-hours postprandial glucose levels decreased in the study group by 26.7% and increased in the control group by 8.2 %.

On the contrary, the results of this study disagree with another studies have been conducted on equally severely diabetic female animals, and approved that moderate endurance exercise training during pregnancy had no effect on fasting or 2-hrs post prandial blood glucose concentration[15].

Another trial disagrees with our results, in which women with GDM were randomized to a home-based exercise program, and they did not find any reduction in blood glucose level in a study conducted by Avery et al., in 1997[8], and this may be due to lack of follow up of these cases which may affect the continuity and the regularity of the program.

Normalizing the macrosomia rate is a primary goal in treating women with pregnancies complicated by gestational diabetes mellitus (GDM). Macrosomia is not only associated with a higher rate of birth injury for the mother and newborn, it is also associated with higher weight as well as, accumulation of fat in childhood and with a higher rate of obesity in adults. While normalizing maternal glucose levels has reduced neonatal morbidity in GDM, the macrosomia rate still has remained elevated compared with the normal obstetrical population[12].

Poor glycemic control leads to increased maternal-fetal transfer of glucose and amino acids as well as fetal hyperinsulinemia. These metabolic changes contribute to the development of macrosomia and can lead to difficult delivery, an increased rate of cesarean section, and an increase in fetal morbidity[11], so another goal for us in this study was decreasing rate of macrosomia in those patients.

According to the studies, animals' offspring from diabetic mothers, who were performing moderate exercise training, had lower body weight at birth relative to that observed in pups from control animals[18]. This comes in agreement with our results as there is significant difference in the new born birth weight, measured immediately after delivery between the two groups (A & B).

In summary, this study had concluded that aerobic exercise in the form of walking on treadmill, at moderate intensity (60-75 % of maximum heart rate), for 45 minutes, 3 times/ week, 1 hour after the main meal and the insulin injection, at 20 weeks' gestation till delivery of the diabetic pregnant women, who had gestational diabetes mellitus, together with diet therapy (1800-2000 kcal/day), improved plasma glucose level and hyperglycemia compared with diet alone. In the study group fasting blood glucose level reduced by 22.8% , 1 hour BGL reduced by 14.3 %, 2 hours BGL reduced by 26.7% and 3 hours BGL reduced by 29,7% after treatment. It was noticed that insulin dosage of the patients in the study group were reduced gradually with continuation of the exercise program and it was less than the dosage of patients in the control group. The new born birth weight in the study group is less than those in the control group by 29.5%. So, it could be said that aerobic exercise in conjunction with diet therapy had a great effect in reducing maternal hyperglycemia and fetal macrosomia in diabetic pregnant women.

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الملخص العربي

تأثير التمرينات الهوائية على ارتفاع مستوى السكر في الدم وعملقة الجنين لدى السيدات المصابات بداء السكر أثناء الحمل

تهدف هذه الدراسة إلى تقييم تأثير التمرينات الهوائية ذات الشدة المتوسطة علي ضبط مستوي ارتفاع سكر الدم أثناء الحمل والحد من زيادة وزن الجنين (عملقة الأجنّة) عند الولادة لدي السيدات الحوامل المصابات بداء السكر . وقد تم إجراء هذا البحث على خمسين سيدة حامل مصابة بسكر الحمل وتراوحت فترة الحمل لكل منهن ما بين الأسبوع العشرين والرابع والعشرين ، وتم تقسيم المريضات إلى مجموعتين متساويتين في العدد : المجموعة الأولى (مجموعة الدراسة) والمجموعة الثانية (المجموعة الضابطة) . تلقت المجموعة الأولى برنامج غذائي متوسط السعرات بالإضافة إلى تمرينات هوائية متوسطة الشدة ، بينما تلقت المجموعة الثانية نفس البرنامج الغذائي فقط . وقد تم تقييم جميع الحالات في المجموعتين باستخدام اختبار السكر بالدم علي مدي ثلاث ساعات قبل العلاج وعند الأسبوع السابع والثلاثين من الحمل . كما تم وزن الجنين بعد الولادة مباشرة لجميع السيدات في المجموعتين . وقد أثبتت نتائج هذه الدراسة أن التمرينات الهوائية ذات الشدة المتوسطة (60-75 % من الحد الأقصى لضربات القلب) لمدة خمس وأربعون دقيقة ثلاث مرات أسبوعيا بعد ساعة من تناول الطعام و تعاطي جرعة الأنسولين مع نظام غذائي متوسط السعرات (1800-2000 سعر حراري) قد أدت لانخفاض مستوى السكر بالدم مقارنة بالنظام الغذائي وحده لدى السيدات الحوامل المصابات بسكر الحمل . وقد انخفضت نسبة السكر بالدم في الصيام عند السيدات في مجموعة الدراسة بنسبة 32.5% وفى الساعة الأولى بعد الطعام بنسبة 14.3% وفى الساعة الثانية بعد الطعام بنسبة 26.7% وفى الساعة الثالثة بعد الطعام بنسبة 36.1% بعد البرنامج العلاجي . كما قل وزن الجنين بعد الولادة في مجموعة الدراسة بنسبة 29.5% مقارنة بوزن الجنين في المجموعة الضابطة وبالتالي فإنه يمكن استخلاص أن التمرينات الهوائية لها تأثير كبير في تقليل معدل ارتفاع سكر الدم وعملقة الأجنّة لدى السيدات المصابات بسكر الحمل .

الكلمات الدالة : الحوامل المصابات بالسكر - تمرينات متوسطة الشدة - سكر الحمل - مستوى السكر بالدم - وزن الجنين عند الولادة - عملقة الأجنّة - اختبار تحمل السكر الفمي .