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Effect of Aerobic Exercises on Insulin Resistance in Obese Pregnant Women

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Authors' contributions

This work was carried out in collaboration between all authors. Author GEE designed the study, wrote the protocol and wrote the first draft of the manuscript. Author HMA managed the literature searches and performed the statistical analysis. Authors HMA and AFE managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aims: This study was conducted to determine the effect of aerobic exercises on insulin resistance in obese pregnant women.
Methodology: 60 primigravidas women between 20-24 weeks gestation diagnosed as having insulin resistance participated in this study. They were selected from the out Patient Clinic of Obstetrics at Kasr El-Aini University Hospital, Faculty of Medicine, Cairo University. Their age ranged 25-35 years, their body mass index ranged from 30-35 kg/m². Participants were assigned randomly into 2groups, participants of group (A) followed moderate restricted diet (1800-2000 kcal/day) in addition to participation in an aerobic exercise program 3 times weekly until end of 37 weeks gestation, while participants of group (B) followed moderate restricted diet (1800-2000 kcal/day) until end of 37 weeks gestation.
Results: The present study revealed that aerobic exercise program produced a significant decrease (P<.001) in insulin resistance level homeostatic model assessment (HOMA) test, fasting blood glucose level & fasting insulin level than the use of moderate restricted diet.
Conclusion: Aerobic exercises are effective in reducing insulin resistance in obesepregnant female if it continued throughout pregnancy.

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1. INTRODUCTION

Insulin resistance (IR) is a condition in which the cells of the body become resistant to the effects of insulin, that is, the normal response to a given amount of insulin is reduced. As a result, higher levels of insulin are needed in order for insulin to have its effects. The resistance is seen with both the body's own insulin (endogenous) and if insulin is given through injection (exogenous) [1].

Insulin resistance (IR) is defined as a subnormal response to both endogenous and exogenous insulin. It is characterized by decreasing sensitivity of target tissues to the action of insulin, by elevated blood glucose concentration, and increased hepatic production of atherogenic lipids. Insulin resistance contributes to the pathophysiology of diabetes, and is a hallmark of obesity, metabolic syndrome, and many cardiovascular diseases. Obesity, mainly of the abdominal type, is associated with resistance to the effects of insulin on peripheral glucose and fatty acid utilization, often leading to type 2 diabetes mellitus [2].

IR is often found in people with visceral adiposity (i.e., a high degree of fatty tissue underneath the abdominal muscle wall as distinct from subcutaneous adiposity or fat between the skin and the muscle wall, especially elsewhere on the body, such as hips or thighs), hypertension, hyperglycemia and dyslipidemia involving elevated triglycerides, small dense low-density lipoprotein particles, and decreased high density lipoprotein cholesterol levels [3]. With respect to visceral adiposity, a great deal of evidence suggests two strong links with IR. First, unlike subcutaneous adipose tissue, visceral adipose cells produce significant amounts of pro inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), and Interleukins-1 and -6, etc. These pro inflammatory cytokines profoundly disrupt normal insulin action in fat and muscle cells, and may be a major factor in causing the whole-body IR observed in patients with visceral adiposity. Second, visceral adiposity is related to an accumulation of fat in the liver, a condition known as nonalcoholic fatty liver disease (NAFLD). The result of NAFLD is an excessive release of free fatty acids into the bloodstream due to increased lipolysis and an increase in hepatic glucose production, both of which have the effect of exacerbating peripheral IR and increasing the likelihood of type-2 diabetes [3].

The rise in IR is associates with increased visceral adiposity and is evidenced by elevated fasting insulin levels as well as, a 50% reduction in insulin sensitivity as measured by a model of glucose kinetics [4]. IR can be related to the metabolic effects of several hormones and cytokines that are elevated in the maternal circulation during pregnancy, potential hormones include human placental lactogen, progesterone, prolactin and cortisol [5].

Resistance to insulin develops in all mothers during pregnancy. In about 2-4%of women this results in temporary diabetes. It happens because pregnant women have less ability to produce extra insulin to overcome this insulin resistance [6].

In the first few weeks of pregnancy, maternal carbohydrate metabolism is affected by a rise in maternal levels of estrogen and progesterone that stimulates pancreatic β-cell hyperplasia and insulin secretion, as pregnancy progress, pancreatic islet cell hypertrophy continues and there is an increased insulin response to glucose or meal stimulation. The overall effect of the metabolic changes during pregnancy is diabetogenic and characterized by resistance to insulin [7].

The most commonly used method to measure IR is homeostasis model assessment of IR (HOMA-IR), derived from the product of fasting glucose and insulin levels, using the following validated formula, (HOMA-IR) = (0.0555 x fasting glucose [mg/dl] x fasting insulin [mU/L] /22.5) [8].

Exercise training has been known to be effective in type 2 diabetes mellitus by increasing insulin sensitivity and strengthens antioxidant defenses and may reduce oxidative stress [9]. Aerobic exercise is a generally accepted therapeutic strategy for type 2 diabetes because it has beneficial effects not only on glycemic profile, but also on reducing metabolic risk factors for cardiovascular diseases including IR. Only a few reports have examined the acute or chronic effect of high intensity exercise on IR [10].

Exercise causes both an increased flow of blood into working muscles and causes blood vessels to expand, because of this combination of blood flow and expand blood vessels, insulin is picked up faster by the blood stream and carried more quickly to the cells that use insulin, so, faster flow

of a large amount of insulin causes body to take up and use the sugar (glucose) in blood, consequently blood sugar then starts to drop faster than usual [11].

Physical activity and weight loss help the body respond better to insulin by losing weight and being more physically active, people with IR or pre diabetes may avoid developing type 2 diabetes [12]. Aerobic exercise is a generally acceptedtherapeutic strategy for type 2 diabetes because it has beneficial effects not only on glycemic profile, but also on reducing metabolic risk factors for cardiovascular diseases including IR. Only a few reports have examined the acute or chronic effect of high intensity exercise on IR [10]. Exercise causes both an increased flow of blood into working muscles and causes blood vessels to expand, because of this combination of blood flow and expand blood vessels, insulin is picked up faster by the blood stream and carried more quickly to the cells that use insulin, so, faster flow of a large amount of insulin causes body to take up and use the sugar (glucose) in blood, consequently blood sugar then starts to drop faster than usual [11].

Physical activity and weight loss help the body respond better to insulin by losing weight and being more physically active, people with IR or pre diabetes may avoid developing type 2 diabetes [12].

1.1 Hypothesis

Aerobic exercises and moderate restricted diet will be more effective than moderate restricted diet in reducing insulin resistance in obesepregnant female.

Inclusive criteria for subject selection:

1. Primigravidas women between 20-24 weeks gestation involved in this study.
2. Women having insulin resistance.
3. Age of subjects ranged from 25-35 years, their body mass index ranged from 30-35 kg/m².

Exclusive criteria for subject selection:

1. Pregnant women with cardiovascular diseases, chest diseases, pre-eclampsia, diabetes.
2. Pregnant women with history of ante -partum hemorrhage, fetal congenital anomalies, low back pain, marked skeletal deformities or previous surgeries at their back or lower limbs.

1.2 Limitation of the Study

This study will be limited by the following factors:

- Psychological status of the pregnant women may affect results of the study.
- Co-operation of the patients may affect results of the study.
- Variation in economic, social and culture level may affect of the study.
- The study group was not representing the whole population. For time limitations, a large number of subjects couldn't be included, which could reflect the more actual results. So further study with much larger population of study subject is recommended in future

1.3 Operational Definitions

Aerobic Exercises: Defined clinically asthephysical exercise that requires additional effort by the heart and lungs to meet the striated muscles' increased demand for oxygen, designed to increase oxygen consumption and improve functioning of the cardiovascular and respiratory systems. Examples of aerobic exercise include running, jogging, swimming, and vigorous dancing or cycling [10].

Insulin resistance: Defined clinically as diminished ability of cells to respond to the action of insulin in transporting glucose from the bloodstream into muscle and other tissues. Insulin resistance typically characterized by metabolic abnormalities, including impaired glucose tolerance, insulin resistance, hypertension, dyslipidemia, central obesity [2].

Diabetes mellitus: Defined clinically as group of metabolic diseases characterized by hyperglycemia resulting from defects in insulin secretion, insulin action, or both.

Diabetes is due to either the pancreas not producing enough insulin, or the cells of the body not responding properly to the insulin produced. There are three main types of diabetes mellitus: Type 1 DM results from the body's failure to produce enough insulin. This form was previously referred to as "insulin-dependent diabetes mellitus" (IDDM) or "juvenile diabetes". The cause is unknown [5].

Type 2 DM begins with insulin resistance, a condition in which cells fail to respond to insulin properly [3]. As the disease progresses a lack of insulin may also develop [6]. This form was previously referred to as non insulin-dependent diabetes mellitus (NIDDM) or "adult-onset diabetes". The primary cause is excessive body weight and not enough exercise [5].

Gestational diabetes, is the third main form and occurs when pregnant women without a previous history of diabetes develop a high blood glucose level [5].

2. MATERIALS AND METHODS

2.1 Design

A randomized controlled trial design was used for the purposes of the current study. Patients were randomized to either group A or B by simple randomization using the envelope method. Accordingly, a pack of sealed envelopes including a card with either the word "Aerobic exercise and moderate restricted diet " or " moderate restricted diet only" written on it, was given to a staff physical therapist unrelated to the study; she/he picked one envelope after patients agreed to take part in the study. Depending on which card was selected patients were allocated to their respective group.

This study was carried out upon a sample of sixty volunteers, primigravidas women diagnosed as having insulin resistance. They were selected randomly from the out Patient Clinic of Obstetrics at Kasr El Ainy University Hospital, Faculty of Medicine, Cairo University. Their ages ranged between (25-35) years and their body mass index ranged from 30 to 35 Kg/m². A detailed medical history was obtained to screen for other pathological conditions, as pregnant women with cardiovascular diseases, chest diseases, pre-eclampsia, diabetes, history of ante -partum hemorrhage, fetal congenital anomalies, marked skeletal deformities were excluded from the study. All pregnant women had a normal single fetus, they were housewives with medium level of education. Their gestational age was calculated from the first day of last menstrual cycle minus date of inclusion in the study, then divided by seven days and confirmed by ultrasonography before starting the study. They were randomly assigned into two equal groups (A& B). All subjects were instructed briefly and clearly about the nature of exercise and its value in order to gain their confidence and co-operation all through the study. Assessment of all patients in both groups (A& B) was carried out before the treatment program and at the end of 37 weeks gestations throughout assessment of fasting blood glucose level, fasting insulin level, HOMA test of insulin resistance were measured immediately following delivery.

Group (A): consisted of thirty women with an average age (29.60 ± 2.61Years(Yrs)) and body mass index(BMI) (32.63±1.15kg/m2) who performed aerobic exercises in addition to followed moderate restricted diet (1800-2000 kcal/day).

1-Exercise training program on bicycle ergometer: duration of each exercise session was 45 minutes and performed at a frequency of three times per week.

Before starting the first session, the treatment procedures were explained to all the pregnant women of group (A) to obtain her confidence and cooperation. The pregnant woman was instructed to take her breakfast one hour before starting the session and empty her bladder to be relaxed. During exercise, woman taught to palpate the uterus for any contractions and to stop exercise if contractions occurred. The duration of each exercise session was 45 minutes and performed at a frequency of three times per week.

The exercise session was divided into:

First stage (warming up): Consisted of 5 minutes warming up in the form of walking in place aimed to prepare the skeletal muscles, the heart and the lungs for the acute phase of the exercise training.

Second stage (Active stage): Consisted of 30 minutes walking on the treadmill without inclination. The pregnant woman was asked to stand on treadmill grasped the handle so the heart rate appeared on the screen then the pregnant women started to walk at steady of speed at 0.7km/hour and increase the speed gradually till reaching 60% of the pregnant woman maximum heart rate. Maximum heart rate of each pregnant woman was calculated by 220-age in years. The heart rate was measured through pulsometer attached to the patient's ear.

Third stage (Cooling down): Consisted of 5 minutes of walking on the treadmill by decreasing the speed gradually, at 40% for maximum heart

rate, to bring the heart rate to its pre exercise level.

2- Moderate restricted diet:

All pregnant women in group (A) were instructed about their diet which was moderate restricted diet limited to (1800-2000) kcal/ day.

- Distribution of calories during the day as follow; 10-20% calories at breakfast, 30%-40% calories at lunch, 20%-30% calories at dinner, 20% calories as snacks in between the main meals.

Diet contained:

- The goal of appropriate dietary management for diabetic woman is to provide adequate nutrition for both the woman and her fetus.
- Protein: 30%-40% proteins, additional protein is required for growth the fetus and the increased size of the maternal blood volume, uterus and breasts. Additional 10 grams (gm) of protein per day is required for this purpose.
- Carbohydrate: 40-50% low glycemic carbohydrate. It is recommended that the carbohydrate content of the diet in a pregnant woman is often less than in the pre-pregnant status.
- Fat: 30% fat, less than one third should saturated fat. No more than one third should be polyunsaturated fat. The remainder should be monosaturated fat.
- Fibers: foods high with soluble fibers.

Group (B): consisted of thirty women with an average age (29.67±3.18Yrs), and BMI (32.50±1.32kg/m2) who followed moderate restricted diet (1800-2000 kcal/day).

Informed consent form was signed by each patient before starting the treatment.

3. RESULTS AND DISCUSSION

3.1 Physical Characteristics of the Patients

As shown in Table (1): The general characteristics for all pregnant women in the two groups (A & B) at entry of the study. Group (A): The means of their age and BMI were (29.60±2.61) years, (32.63±1.15)Kg/m2 respectively. Group (B): The means of their age and BMI were (29.67±3.18) years and (32.50±1.32) Kg/m^2 respectively.

Table 1. Physical characteristics of the patients before the treatment

Groups	Age (yrs.)	BMI(kg/m2)
Group (A)	29.60±2.61	32.63±1.15
Group (B)	29.67±3.18	32.50±1.32

Yrs: years; BMI: body mass index

3.2 Statistical Analysis

The collected data was statistically analyzed by using unpaired t test to compare between mean values of different variables in the two studied groups while comparison between 24 weeks and 37 weeks of gestation within the same group was performed using paired t test. Statistical Package for the Social Sciences (SPSS) computer program (version 16 windows) was used for data analysis. Data were represented as means and standard deviations and percentage of change was calculated. It was considered significant at P value<0.05 and highly significant at P-value<0.001.

The results of this study showed that, insulin resistance level (HOMA) test, fasting blood glucose level & fasting insulin level improved in both groups A&B after treatment as shown in (Tables 2, 3 and 4).

3.2.1 Comparison between both groups

3.2.1.1 Fasting glucose level

There was no significant difference between both groups A&B in fasting glucose level before the treatment. While there was a significant difference between both groups after the end of treatment. Then a pair wise comparison was conducted using the unpaired T-test to compare the mean value of the fasting blood glucose level at entry of the study on 24th weeks and at 37 weeks' gestation revealed that group (A) showed statistically significant improvement than group (B).

Regarding Group (A): the mean values at entry of the study on 24th weeks and at 37weeks' gestation were (7.55±0.66 &4.93±0.46mmol/l) respectively, the percentage of improvement was 34.7%. Showed statistically highly significant decrease (P<0.001). While in group (B): the

mean values at entry of the study on 24th weeks and at 37 weeks' gestation were (7.63±0.65&5.89±0.47mmol/l)) respectively, the percentage of improvement was 22.8%. Showed statistically highly significant decrease (P<0.001).

So, regarding fasting glucose level group (A) showed statistically significant improvement than group (b) as shown in (Table 2).

3.2.1.2 Fasting insulin level

As shown in (Table 3), there was no significant difference between both groups A&B in fasting insulin level before the treatment. While there was a significant difference between both groups after the end of treatment. Then a pair wise comparison was conducted using the unpaired T-test to compare the mean value of the fasting blood insulin level at entry of the study on 24th weeks and at 37 weeks' gestation revealed that group (A) showed statistically significant improvement than group (B).

Regarding Group (A): The mean values at entry of the study on 24th weeks and at 37weeks' gestation were (18.46±1.52&11.83±1.47 IU/l) respectively, the percentage of improvement was 35.9%. Showed statistically highly significant decrease. While in group (B): the mean values at entryof the study on 24th weeks and at 37 weeks' gestation were (19.25±2.03 & 12.36±0.91IU/l) respectively, the percentage of improvement was 35.8%. Showed statistically highly significant decrease.

So, regarding fasting insulin level group (A) showed statistically significant improvement than group (b) as shown in (Table 3).

3.2.1.3 Insulin resistance (HOMA test)

As shown in (Table 4), there was no significant difference between both groups A&B in insulin resistance (HOMA test) before the treatment. While there was a significant difference between both groups after the end of treatment. Then a pair wise comparison was conducted using the unpaired T-test to compare in the mean value of the insulin resistance at entry of the study on 24th weeks and at 37 weeks' gestation revealed that group (A) showed statistically significant improvement than group (B).

Regarding Group (A): The mean values at entry of the study on 24th weeks and at 37weeks' gestation were (6.15±0.62 & 2.56±0.43) respectively, the percentage of improvement was 58.4%. Showed statistically highly significant decrease. While in group (B): the mean values at entryof the study on 24th weeks and at 37 weeks' gestation were (6.47±0.85 & 3.19±0.41) respectively, the percentage of improvement was 50.7%. Showed statistically highly significant decrease.

So, regarding Insulin resistance group (A) showed statistically significant improvement than group (b) as shown in (Table 4).

Table 2. Comparison between the mean values of fasting glucose value (mmol/L) measured before- and after study for both groups

	24 wks (n= 30)	37 wks (n= 30)	% improvement	p value
Group A	7.55±0.66	4.93±0.46	34.7	0.001**
Group B	7.63±0.65	5.89±0.47	22.8	0.001**
p value	0.636	0.001**	---	---

*Data are expressed as mean ± SD. NS= p> 0.05= not significant; **p< 0.01= highly significant*

Table 3. Comparison between the mean values of fasting insulin value (IU/l) measured before- and after study for both groups

	24 wks (n= 30)	37 wks (n= 30)	% improvement	p value
Group A	18.46±1.52	11.83±1.47	35.9	0.001**
Group B	19.25±2.03	12.36±0.91	35.8	0.001**
p value	0.095	0.097	---	---

*Data are expressed as mean ± SD. p>0.05= not significant; **p<0.01= highly significant*

Table 4. Comparison between the mean values of homa value (iu/l) measured before- and after study for both groups

	24 wks (n= 30)	37 wks (n= 30)	% improvement	p value
Group A	6.15±0.62	2.56±0.43	58.4	0.001
Group B	6.47±0.85	3.19±0.41	50.7	0.001**
p value	0.105	0.001**	---	---

*Data are expressed as mean ± SD. p> 0.05= not significant; **p<0.01= highly significant*

3.3 Discussion

Results of the presenting study revealed that, aerobic exercise in the form of walking on treadmill, at moderate intensity (60% of maximum heart rate), for 35 minutes, 3 times/ week, at 20 -24 weeks' gestation until end of 37 weeks' gestations of the insulin resistance pregnant women, together with diet therapy (1800-2000 kcal/day) appears to be more effective than diet alone in improving insulin resistance level .

Physical activity has long been known for its role in improving glucose homeostasis through its direct or indirect impact on insulin sensitivity via several mechanisms. Physical activity has independent effects on glucose disposal by increasing both insulin-mediated and non–insulin-mediated glucose disposal which can also exert long-term effects on improvement in insulin sensitivity through increased fat-free mass. The benefits of preventing or delaying the onset of type 2 diabetes among nonpregnant individuals have been reported repeatedly, therefore, physical activity may have the potential for preventing gestational diabetes mellitus (GDM) and related adverse health outcomes [13].

The present study revealed that aerobic exercise, at 20 -24 weeks' gestation until end of 37 weeks' gestations of the insulin resistance pregnant women, together with diet therapy (1800-2000 kcal/day), in the participants of group (A), produces a statistically highly significant decrease (P<0.001) of fasting blood glucose level by a percentage of 34.7%, compared to 22.8% % in the participants of group (B).

The reduction which occurs in fasting blood glucose level after performing the aerobic exercises supported by Vicentia et al. [14] who explained that metabolic effects of a single 15-minute session at 30% VO2 max (maximal oxygen consumption) in type-2 diabetic pregnant women and concluded that the low intensity exercise level was safe and, if repeated regularly, may help reverse glucose intolerance and decrease exogenous insulin requirements. Also ACOG[15], recommends that exercise heart rates should not exceed 140 beat/minute (40-60% of VO2max).The result of this study are in line with Michelle et al. [16] who stated that physical exercise has been shown to improve glucose tolerance and blunt the insulin response to a glucose load in insulin-resistant individuals.

Also, The present study revealed that aerobic exercise, at 20 -24 weeks' gestation until end of 37 weeks' gestations of the insulin resistance pregnant women, together with diet therapy (1800-2000 kcal/day), in the participants of group (A), produces a statistically highly significant decrease (P<0.001) of fasting blood insulin level by a percentage of 35.9 % compared to 35.8 in the participants of group (B).

The reduction which occurs in fasting insulin level after performing the aerobic exercises supported by Richter and Galbo [17] and Ibanez et al.[9] who explained that the duration of the exercise program should be 45 minutes, and a meal should be consumed 1-3 hours before the exercise, higher levels of insulin sensitivity are associated with improved metabolic profile, endurance training may preferentially improve glucose effectiveness. Also Solomon et al. [18] suggested that exercise training improved insulin sensitivity.

Finally, The present study revealed that aerobic exercise, at 20 -24 weeks' gestationuntil end of 37 weeks' gestations of the insulin resistance pregnant women, together with diet therapy (1800-2000 kcal/day), in the participants of group (A), produces a statistically highly significant decrease (P<0.001) of insulin resistance level (HOMA) test by a percentage of 58.4% compared to 50.7% in the participants of group (B).

The reduction which occurs in insulin resistance level after performing the aerobic exercises supported by James [19] suggests that both diet and exercise can alter the usual increase in insulin resistance seen in Western societies during mid and late pregnancy. A low-glycemic diet combined with a low-volume exercise regimen during pregnancy decreases the glucose and insulin response to both mixed caloric intake and exercise, and probably lowers both 24-hours blood glucose concentrations and the maternal substrate utilization ratio of carbohydrate/fat.

Also agree with Solomon et al. [18] who suggest that exercise appears to be effective in normalizing glucose tolerance (GT) only in patients who still have an adequate capacity to secrete insulin, and in whom insulin resistance is the major cause for abnormal GT. The amount of exercise required to normalize GT in such patients appears to be in the range of 25 to 35 km per week of running, or a comparable amount of another form of exercise, performed on a regular basis.

4. CONCLUSION

In summary, this research study had approved that aerobic exercise in the form of walking on treadmill, at moderate intensity (60% of maximum heart rate), for 35 minutes, 3 times/ week, at 20 -24 weeks' gestation until end of 37 weeks' gestations of the insulin resistance of obese pregnant women, together with diet therapy (1800-2000 kcal/day), improved insulin resistance level compared with diet alone.

5. RECOMMENDATIONS FOR FURTHER RESEARCH

By the end of this study, the obtained results would encourage further recommendations for obstetricians to encourage insulin resistance obese pregnant women to engage in a physical therapy program consisting of aerobic exercise at moderate intensity and diet therapy during their pregnancies for controlling insulin resistance. Future research should shed light on the effect of different intensities of aerobic exercises (light, moderate and vigorous) on reducing insulin resistance in obese pregnant.

CONSENT

All authors declare that 'written informed consent was obtained from the patient before starting the study for publication of this case report.

ETHICAL APPROVAL

This study was approved by ethical committee of faculty of Physical Therapy, Cairo, University.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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