Resistance exercise decreases the need for insulin in overweight women with gestational diabetes mellitus

Gabrielle N. Brankston, MSc,* B. F. Mitchell, MD, Edmond A. Ryan, MD, Nanette B. Okun, MD

Perinatal Research Centre, University of Alberta, Edmonton, Alberta, Canada

Objective: This study examines the effects of circuit-type resistance training on the need for insulin in women with gestational diabetes mellitus.

Study design: Thirty-two patients with gestational diabetes mellitus were randomly assigned either to a group that was treated with diet alone or to a group that was treated with diet plus resistance exercise.

Results: The number of women whose condition required insulin therapy was the same, regardless of treatment. However, a subgroup analysis that examined only overweight women (prepregnant body mass index, > 25 kg/m^2) showed a lower incidence of insulin use in the diet-plus-exercise group ($P < .05$). Women in the diet-plus-exercise group were prescribed less insulin ($P < .05$) and showed a longer delay from diagnosis to the initiation of insulin therapy ($P < .05$), compared with the diet-alone group.

Conclusion: Resistance exercise training may help to avoid insulin therapy for overweight women with gestational diabetes mellitus.

Gestational diabetes mellitus (GDM) is defined as carbohydrate intolerance of variable severity with onset or first recognition during pregnancy.[1] The diagnosis of carbohydrate intolerance has implications for both the baby and mother that include macrosomia, with the risk of fetal and maternal birth trauma and neonatal hypoglycemia.[2] Women with a diagnosis of GDM have a 35% to 50% chance of recurrence in future pregnancies.[3,4] Furthermore, 40% to 60% of women with GDM will exhibit further deterioration of carbohydrate metabolism, and type 2 diabetes mellitus will develop as they age.[5,6]

Current treatment of GDM includes blood glucose monitoring, dietary counseling, increased fetal surveillance, and insulin therapy as needed to achieve and maintain normoglycemia. Although insulin therapy has been shown to be effective in the reduction of the rate of macrosomia in women with GDM,[7] the use of insulin is potentially stressful and does not rectify peripheral insulin resistance, which is important in the cause of GDM.[8] In addition, the aggressive use of insulin may result in an increased incidence of small-for-gestational-age infants.[9]

* Reprint requests: Gabrielle Brankston, MSc, 11128 75 Ave, Edmonton, AB, T6G 0H2.
E-mail: gnb@ualberta.ca

Exercise can provide benefits to women with GDM that insulin cannot. Exercise has been shown to decrease peripheral insulin resistance[10,11] and may be more acceptable to many women than daily insulin injections.

Aerobic exercise uses large muscle groups rhythmically and continuously for a sustained period of 15 to 20 minutes or longer while maintaining 60% to 80% of the maximum heart rate. In contrast, resistance exercise refers to overloading a muscle through a specific range of motion with the use of some type of a resistance device. Two randomized studies have provided evidence that aerobic training will lower blood glucose levels consistently in GDM.[12,13] Results of these studies demonstrate that aerobic exercise with a frequency as low as three times per week may eliminate the need for insulin therapy in women with GDM.[12]

Resistance exercise may provide a viable alternative to aerobic exercise to treat GDM. Participation in circuit-type resistance training has been shown to improve insulin sensitivity,[11,14] glucose disposal rate,[14] and glycemic control in people with type 2 diabetes mellitus.[11,15-17] Smutok et al[10] demonstrated that strength training improves glucose tolerance to the same extent as aerobic training in men with abnormal glucose regulation. Given the similarity in cause between GDM and type 2 diabetes mellitus, it is possible that the blood glucose–lowering effect of resistance exercise may also be seen in women with GDM.

A possible advantage of resistance exercise during pregnancy may be improved strength and posture, with the avoidance of the discomfort that accompanies the progressive anterior shift in the center of gravity.[18] Women may find aerobic training increasingly uncomfortable as the pregnancy progresses. Exercises that use the upper body or place little mechanical stress on the trunk produce no uterine activity[19] and may be more comfortable later in pregnancy. Muscle-conditioning exercises may be performed more easily than aerobic exercise during late pregnancy, because women can remain relatively stationary throughout the exercise. In addition, having a greater number of exercise options may enhance compliance with an exercise program overall.

The current investigation examines the effects of circuit-type resistance training on the need for insulin in women with GDM who were cared for at one of two perinatal units in Edmonton, Alberta, Canada. We hypothesized that resistance exercise training would eliminate or significantly reduce the need for insulin in women with GDM.

Methods

A preliminary chart review showed that approximately 50% of women with GDM in the Edmonton area are prescribed insulin treatment. To calculate the sample size, it was estimated that the incidence of insulin use would need to be reduced to 25% to be considered clinically significant. For 0.8 power and an α value of .05, 32 subjects would be required, equally randomized into each of the two groups to demonstrate statistical significance.

GDM was diagnosed in accordance with the Canadian Diabetes Association guidelines.[20] The screening test is a measurement of plasma glucose level 1 hour after a 50-g oral glucose load that was given at any time of day. Women with levels of ≥ 10.3 mmol/L (185 mg/dL) were diagnosed with GDM. The second diagnostic method was the oral glucose tolerance test that measures the fasting plasma glucose level and the plasma glucose levels at 1 and 2 hours after the ingestion of a 75-g glucose load. If two of the following three values were met or exceeded, a diagnosis of GDM was established: fasting, ≥ 5.3 mmol/L (95 mg/dL); 1 hour, ≥ 10.6 mmol/L (191 mg/dL); 2 hours, ≥ 8.9 mmol/L (160 mg/dL).

Thirty-eight otherwise healthy pregnant women with GDM were recruited into the study. All subjects provided written informed consent before entering the study. Subjects were recruited from the Diabetic Outpatient Clinics at the Royal Alexandra and Grey Nuns Hospitals in Edmonton, Alberta, Canada. Inclusion criteria included maternal age between 20 and 40 years, gestational age between 26 and 32 weeks, body mass index (BMI) below 40 kg/m^2, and nonsmokers who were not involved in a regular exercise program. The study was approved by the University of Alberta Health Research Ethics Board. Subjects were assigned randomly to groups with the use of a random numbers table. Allocation was concealed in sequentially numbered opaque envelopes.

All subjects who were assigned randomly to the diet-alone group were treated with a standard diabetic diet that consisted of 40% carbohydrate, 20% protein, and 40% fat, which was calculated at 24 to 30 kcal/kg per day on the basis of the subject's ideal prepregnant body weight, and divided into three meals and three snacks. Ideal body weight is defined as having a BMI between 20 kg/m^2 to 25 kg/m^2. Weight gain was monitored weekly. The women in this group were asked not to begin a structured exercise program for the remainder of the pregnancy.

Women who were assigned randomly to the diet-plus-resistance exercise group followed the same standard diet while participating in a progressive physical conditioning program. An experienced instructor (G. N. B.) supervised three introductory sessions and made weekly contact to ensure the safety of participants and to encourage adherence to the exercise program. Subjects in the exercise group were instructed to perform circuit-type resistance training three times per week. Eight exercises were performed in a continuous, circuit-type fashion with short rests (<1 minute) between the

Table I Demographic characteristics

Characteristic	Diet alone (n = 16)	Diet plus exercise (n = 16)	P value
Maternal age (y)	31.3 ± 5.0	30.5 ± 4.4	.63
Height (cm)	165.1 ± 8.5	159.6 ± 7.1	.06
Prepregnant body mass (kg)	77.1 ± 19.2*	65.9 ± 8.4	<.05
Prepregnant BMI (kg/m^2)	28.0 ± 5.7	25.9 ± 3.4	.21
Gestational age at first visit (wk)	29.6 ± 2.1	29.0 ± 2.0	.44
Weight gain up to diagnosis (kg)	9.5 ± 4.8	10.4 ± 3.5	.56
Total pregnancy weight gain (kg)	11.2 ± 5.7	11.3 ± 4.4	.96
History of GDM (n)	3	3	1

Values are means ± SD.

   * Significant difference between diet alone and diet plus exercise groups.

stations. Exercises included pliés (ie, squats with out-turned knees), military press, knee extension, hamstring curl, bench press, lateral pull down, seated row, and triceps press. All exercises were modified for the use of rubber tubing instead of weights. Subjects were instructed to exercise at a level that felt "somewhat hard." As the exercises became easier to perform, subjects were instructed to perform the exercises farther away from the point at which the tubing was anchored. This was done to maintain the exercise intensity. The progression of the exercise program was as follows: week 1, 2 sets of 15 repetitions of each exercise; week 2, 2 sets of 15 repetitions; week 3, 3 sets of 15 repetitions; week 4 to delivery, 3 sets of 20 repetitions. Subjects were taught to monitor their own heart rate during exercise to ensure that it did not rise above 140 beats/min. All exercise sessions were recorded in a log book.

The glucose monitoring in both groups included daily fasting and 1- or 2-hour postprandial measurements with portable glucometers that had memory capabilities. A random glucose measurement was taken in a reference laboratory at least once during treatment to ensure the accuracy of the meter. Insulin therapy was initiated if any of the following three values were exceeded consistently at any time during diet therapy: mean fasting, ≥5.3 mmol/L (95 mg/dL); mean 1-hour postprandial, ≥7.8 mmol/L (140 mg/dL); or 2-hour postprandial, ≥6.7 mmol/L (120 mg/dL).

These values also represent the goals of insulin therapy. Insulin regimens were individualized for each patient. Those patients for whom insulin was prescribed were given short-acting insulin before meals and intermediate-acting insulin at bedtime.

The primary end point of the study was the requirement for insulin in women with GDM. Analysis was by intent-to-treat. Secondary end points included latency to insulin treatment and the amount of insulin that was required. Neonatal outcomes included gestational age at delivery and birth weight.

The χ^2 test was used to analyze the primary end point of requirement for insulin. The independent samples t test was used to analyze the secondary end points. Variables that were not distributed normally were analyzed with the Mann-Whitney U test.

Results

Thirty-eight women were recruited. Because of pregnancy-induced hypertension, the physicians of three women advised against the exercise program. Two women who were assigned randomly to exercise did not enter the program. One patient dropped from the study because of time constraints. Thirty-two women completed the study.

The groups were similar in physical characteristics (Table I). The diet-alone group had a significantly higher mean prepregnant body mass (weight) compared with the diet-plus-exercise group, but no significant difference was noted in prepregnant BMI.

Table II displays the diagnostic results for GDM. Seven women in the diet-alone group and nine women in the diet-plus-exercise group met the diagnostic criteria of GDM with a 50-g glucose challenge test alone. The remainder of the women were diagnosed with a 75-g oral glucose tolerance test. Fasting and 1-hour values were significantly higher in the diet-alone group. However, there were no significant differences between groups with regard to the 2-hour measurement.

The diet-plus-exercise group participated in an average of 2.0 ± 0.9 sessions of resistance exercise per week. The diet-alone group reported little activity other than walking. Overall, the number of women whose condition required insulin treatment was not significantly different between the two groups (Table III). Within the diet-plus-exercise group, 30% of the women who exercised 2 to 3 times per week were prescribed insulin therapy; 67% of those women who exercised 0 to 1.9 times per week were prescribed insulin therapy.

The amount of insulin that was prescribed was significantly lower in the diet-plus-exercise group compared with the diet-alone group (Table III). The latency period between the first clinic visit and the initiation of insulin therapy was significantly longer in the diet-plus-exercise group compared with the diet-alone group (Table III). There were no significant differences between the diet-alone and diet-plus-exercise groups in gestational age at delivery, rate of caesarean deliveries, or birth weight.

A subgroup analysis that examined only the women who had a prepregnant BMI of >25 kg/m^2 showed a significantly lower incidence of insulin use in the diet-plus-exercise group. In this analysis, 8 of 10 women in the

Table II Diagnostic information

Diagnostic test (mmol/L)	Diet alone	Diet plus exercise	P value
GDM screen	11.6 ± 1.1*	11.1 ± 0.8[†]	.37
Glucose tolerance test			
Fasting	5.5 ± 0.6[‡§]	4.8 ± 0.6[‖]	.03
1 Hour	12.2 ± 0.8[‡§]	11.3 ± 0.6[‖]	.03
2 Hour	9.6 ± 1.4[‡]	9.9 ± 1.0[‖]	.61

Values are means ± SD.
 * n = 7.
 [†] n = 9.
 [‡] n = 9.
 [§] Significant difference between diet alone and diet plus exercise groups.
 [‖] n = 7.

Table III Outcomes

Outcome	Diet alone (n = 16)	Diet plus exercise (n = 16)	P value
Required insulin (n)	9 (56.3%)	7 (43.8%)	.48
Amount of insulin required (units/kg)	0.48 ± 0.3*	0.22 ± 0.2	<.05
Latency to insulin requirement (wk)	1.11 ± 0.8*	3.71 ± 3.1	<.05

Values are means ± SD, except where indicated.
 * Significant difference between diet alone and diet plus exercise groups.

Table IV Home-monitored blood glucose levels

Blood glucose (mmol/L)	Diet alone (n = 12)	Diet plus exercise (n = 12)	P value
Fasting	5.1 ± 0.65	4.7 ± 0.39	.07
Breakfast (2 h)	6.2 ± 1.1	5.7 ± 0.40	.12
Lunch (2 h)	6.2 ± 0.72	5.9 ± 0.43	.12
Supper (2 h)	6.7 ± 0.83	6.4 ± 0.52	.34
Pooled postmeal (2 h)	6.4 ± 0.81*	6.0 ± 0.29	<.05

Values are means ± SD.
 * Significant difference between diet alone and diet plus exercise groups.

Table V Demographic characteristics based on requirement for insulin therapy

Characteristic	Insulin (n = 16)	No insulin (n = 16)	P value
Maternal age (y)	31.9 ± 4.9	29.9 ± 4.3	.2
Gestational age at first visit (wk)	28.8 ± 2.1	29.7 ± 1.9	.3
Prepregnant BMI (kg/m^2)	28.3 ± 5.6	25.6 ± 3.3	.1
Weight gain up to diagnosis (kg)	9.2 ± 4.3	10.7 ± 4.0	.3
Total pregnancy weight gain (kg)	10.8 ± 5.0	11.7 ± 5.0	.6
GDM screen (mmol/L)	11.3 ± 1.0*	11.4 ± 0.9[†]	.9
Glucose tolerance test (mmol/L)			
Fasting	5.4 ± 0.7[‡]	5.0 ± 0.6[§]	.3
1 h	12.3 ± 1.0[‡]	11.5 ± 0.9[§]	.2
2 h	10.5 ± 1.4[‡‖]	9.1 ± 0.6[§]	<.05

Values are means ± SD.
 * n = 9.
 [†] n = 7.
 [‡] n = 7.
 [§] n = 9.
 [‖] Significant difference between insulin and no insulin groups.

diet-alone group were prescribed insulin therapy; only 3 of 10 women in the diet-plus-exercise group were prescribed insulin (P < .05).

There were no differences between the treatment groups regarding home-monitored blood glucose measurements (Table IV). However, when all postmeal values were pooled, the diet-plus-exercise group demonstrated lower blood glucose values compared with the diet-alone group. Four women in each group did not record their blood glucose measurements adequately.

Table V displays the demographic and diagnostic information for the women who were prescribed insulin versus the women who were not prescribed insulin, regardless of treatment group assignment.

Comment

The objective of this study was to determine the effect of resistance exercise training on the requirement for insulin therapy among women with GDM. The results demonstrate that, in our sample population, resistance training did not reduce significantly the number of women who were prescribed insulin to treat persistent hyperglycemia. The power to detect a 25% difference

in insulin requirement was approximately 55%. Fifty-six subjects would have been required to demonstrate that the effect that was shown (12.5%) was significant. Although this study did not have the power to show a significant difference in the primary outcome, the analyses of secondary variables support a beneficial effect of resistance exercise in accordance with our hypothesis.

The women in the diet-plus-exercise group were prescribed significantly less insulin and had a significantly longer latency period to insulin use than those women in the diet-alone group, which would suggest that resistance training has a positive influence on glycemic control.

The finding of a greater effect of resistance exercise among the overweight women with GDM is consistent with the results of Dye et al.[21] This large retrospective study demonstrated that lean women had similar rates of GDM, whether they exercised during pregnancy or

not. In contrast, obese women who exercised during their pregnancy had lower rates of GDM than their nonexercising counterparts. In addition, the findings of Avery and Walker[22] suggested a greater effect of aerobic exercise on women with GDM who are overweight compared with those with normal weight, which implies that exercise is useful particularly in the treatment of GDM in overweight women.

The findings suggest that there is a difference in the mechanism of GDM in normal weight women versus overweight women. GDM may represent a spectrum of abnormalities with insulin resistance and a beta-cell defect both playing a role. It is possible that GDM in lean women is largely due to a beta-cell defect, which is not corrected with exercise, whereas overweight women may have a more pronounced peripheral insulin resistance as the mechanism.

Exercise training is likely to exert its effect by improving peripheral insulin resistance. Evidence shows that the strongest protective effect of exercise in the prevention of type 2 diabetes mellitus occurs among obese individuals,[23,24] who are more likely to have insulin resistance. It would follow that exercise training is more beneficial to overweight women with GDM.

Previous research that used aerobic exercise as an alternative treatment for GDM has demonstrated positive results. Jovanovic-Peterson et al[13] showed that women who exercised 3 times per week had significantly lower fasting and postprandial blood glucose values than those of a group that was treated with diet alone. However, there was no reference to the relationship of the effect of this aerobic exercise to maternal body composition. Bung et al[12] randomly assigned obese women with GDM whose condition did not respond to diet therapy to either an insulin group or an aerobic exercise group. No significant differences were found in weekly blood glucose determinations between the groups, which suggest that aerobic exercise is just as effective as insulin in the treatment of GDM.

We are not aware of another study that has examined the effect of resistance exercise training among women with GDM. Previous investigation has examined subjects with type 2 diabetes mellitus in whom resistance exercise training has been found to be effective in controlling blood glucose. Ishii et al[14] demonstrated that circuit-type resistance training increased the insulin-stimulated glucose disposal rate by 48% in previously untrained type 2 diabetic men. These subjects participated in five training sessions per week for 4 to 6 weeks. Similarly, men and women with type 2 diabetes mellitus who participated in a 3-month circuit resistance training program demonstrated significant improvements in hemoglobin A1C and improvements in home-monitored blood glucose levels.[15] Interestingly, the use of antidiabetic drugs was discontinued in one individual because of hypoglycemia. In addition, men with impaired glucose tolerance who participated in a 20-week resistance-training program were found to have normalized glucose tolerance such that they were reclassified as nondiabetic.[10]

Given that resistance exercise training reduced the amount of insulin that was required in our population of women with GDM, beginning an exercise program earlier in pregnancy may be even more advantageous. Indeed, Jovanovic-Peterson et al[13] demonstrated that the effect of aerobic exercise among women with GDM was not seen until the fourth week of training. Correspondingly, in the present study, subjects in the diet-plus-exercise group were prescribed insulin an average of 3.7 weeks after the first clinic visit. Perhaps involving at-risk women in an exercise program early in pregnancy would either prevent GDM or at least eliminate the need for insulin as part of their treatment.

Adherence to the exercise program was satisfactory because women in this group exercised an average of two sessions per week of the three sessions that had been suggested. Compliance to aerobic exercise programs in previous studies that involved women with GDM had been 90% to 100% for supervised programs[12,13] and 75% to 100% for home-based programs.[25] The reduced amount of insulin that was required by the diet-plus-exercise group and the trend of reduced insulin requirement with increased exercise frequency in the current study indicates that, if compliance had been 100%, more women may have obviated insulin treatment. A limitation of this study is the lack of assessment of adherence to the diet advice. Because there was no analysis of dietary changes in the current investigation, it is impossible to estimate the effect that changes in the diet had on blood glucose.

An additional limitation of this study is the significantly higher initial levels of hyperglycemia in the diet-alone group compared with the diet-plus-exercise group. Higher initial levels of hyperglycemia may have been a predictor of a higher probability of insulin requirement. However, the difference was seen only in the subset of women who received the diagnosis with the oral glucose tolerance test. In addition, there were no differences between the groups regarding the GDM screen. Furthermore, total postprandial home-monitored blood glucose levels remained higher in the diet-alone group, despite the prescription of more insulin than for the diet-plus-exercise group.

The outcome of this study has important implications for the treatment of GDM. An investigation with a larger sample size is needed to confirm that resistance training is an effective alternative in lowering the need for insulin therapy. Future investigations should compare resistance training to insulin therapy in those women whose condition does not respond to diet therapy. In addition, a direct comparison should be made between aerobic and resistance training in women with

GDM. Research is also needed to determine whether interventions with resistance training would help to prevent GDM.

References

1. Metzger BE, Coustan DR. Summary and recommendations of the fourth international workshop-conference on gestational diabetes mellitus. Diabetes Care 1998;21(Suppl):B161-7.

2. Jimenez-Moleon JJ, Bueno-Cavanillas A, Luna-del-Castillo Jde D, Garcia-Martin M, Lardelli-Claret P, Galvez-Vargas R. Impact of different levels of carbohydrate intolerance on neonatal outcomes classically associated with gestational diabetes mellitus. Eur J Obstet Gynecol Reprod Biol 2002;102:36-41.

3. Gaudier FL, Hauth JC, Poist M, Corbett D, Cliver SP. Recurrence of gestational diabetes mellitus. Obstet Gynecol 1992;80: 755-8.

4. Moses RG. The recurrence rate of gestational diabetes in subsequent pregnancies. Diabetes Care 1996;19:1349-50.

5. Henry OA, Beischer NA. Long-term implications of gestational diabetes for the mother. Baillieres Clin Obstet Gynaecol 1991;5: 461-83.

6. O'Sullivan JB. Diabetes mellitus after GDM. Diabetes 1991; 40(Suppl):131-5.

7. Coustan DR, Imarah J. Prophylactic insulin treatment of gestational diabetes reduces the incidence of macrosomia, operative delivery, and birth trauma. Am J Obstet Gynecol 1984;150: 836-42.

8. Kuhl C. Etiology and pathogenesis of gestational diabetes. Diabetes Care 1998;21:B19-26.

9. Langer O, Levy J, Brustman L, Anyaegbunam A, Merkatz R, Divon M. Glycemic control in gestational diabetes mellitus: how tight is tight enough? Small for gestational age versus large for gestational age. Am J Obstet Gynecol 1989;161:646-53.

10. Smutok MA, Reece C, Kokkinos PF, Farmer CM, Dawson PK, DeVane J, et al. Effects of exercise training modality on glucose tolerance in men with abnormal glucose regulation. Int J Sports Med 1994;15:283-9.

11. Eriksson J, Tuominen J, Valle T, Sundberg S, Sovijarvi A, Lindholm H, et al. Aerobic endurance exercise or circuit-type resistance training for individuals with impaired glucose tolerance? Horm Metab Res 1998;30:37-41.

12. Bung P, Artal R, Khodiguian N, Kjos S. Exercise in gestational diabetes: An optional therapeutic approach? Diabetes 1991; 40(Suppl):182-5.

13. Jovanovic-Peterson L, Durak EP, Peterson CM. Randomized trial of diet versus diet plus cardiovascular conditioning on glucose levels in gestational diabetes. Am J Obstet Gynecol 1989;161: 415-9.

14. Ishii T, Yamakita T, Sato T, Tanaka S, Fujii S. Resistance training improves insulin sensitivity in NIDDM subjects without altering maximal oxygen uptake. Diabetes Care 1998;21:1353-5.

15. Eriksson J, Taimela S, Eriksson K, Parviainen S, Peltonen J, Kujala U. Resistance training in the treatment of non-insulin dependent diabetes mellitus. Int J Sports Med 1997;18:242-6.

16. Dunstan DW, Puddey IB, Beilin LJ, Burke V, Morton AR, Stanton KG. Effects of a short-term circuit weight training program on glycaemic control in NIDDM. Diabetes Res Clin Pract 1998;40:53-61.

17. Honkola A, Forsen T, Eriksson J. Resistance training improves the metabolic profile in individuals with type 2 diabetes. Acta Diabetol 1997;34:245-8.

18. Hall DC, Kaufmann DA. Effects of aerobic and strength conditioning on pregnancy outcomes. Am J Obstet Gynecol 1987;157:1199-203.

19. Durak EP, Jovanovic-Peterson L, Peterson CM. Comparative evaluation of uterine response to exercise on five aerobic machines. Am J Obstet Gynecol 1990;162:754-6.

20. Meltzer S, Leiter L, Daneman D, Gerstein HC, Lau D, Ludwig S, et al. 1998 clinical practice guidelines for the management of diabetes in Canada: Canadian Diabetes Association. CMAJ 1998; 159:S1-S29.

21. Dye TD, Knox KL, Artal R, Aubry RH, Wojtowycz MA. Physical activity, obesity, and diabetes in pregnancy. Am J Epidemiol 1997; 146:961-5.

22. Avery MD, Walker AJ. Acute effect of exercise on blood glucose and insulin levels in women with gestational diabetes. J Matern Fetal Med 2001;10:52-8.

23. Helmrich SP, Ragland DR, Paffenbarger RS. Prevention of non-insulin-dependent diabetes mellitus with physical activity. Med Sci Sports Exerc 1994;26:824-30.

24. Manson JE, Nathan DM, Krolewski AS, Stampfer MJ, Willett WC, Hennekens CH. A prospective study of exercise and incidence of diabetes among US male physicians. JAMA 1992;268:63-7.

25. Avery MD, Leon AS, Kopher RA. Effects of a partially home-based exercise program for women with gestational diabetes. Obstet Gynecol 1997;89:10-5.