Resistance exercise and glycemic control in women with gestational diabetes mellitus

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OBJECTIVE: The objective of the study was to evaluate the effect of a resistance exercise program with an elastic band on insulin requirement and glycemic control in patients with gestational diabetes mellitus (GDM).

STUDY DESIGN: Sixty-four patients with gestational diabetes mellitus were randomly assigned into 2 groups: an exercise group (EG; n = 32) and a control group not submitted to the exercise program (CG; n = 32).

RESULTS: A significant reduction in the number of patients who required insulin was observed in the EG (7/32) compared with the CG group (11/32) (P = .005). The percentage of time spent within the proposed target glucose range (of at least 80% of weekly measurements below the limits preestablished for the disease) was significantly higher in EG compared with the CG group (EG = 0.63 ± 0.30; CG = 0.41 ± 0.31; P = .006).

CONCLUSION: The resistance exercise program was effective in reducing the number of patients with GDM who required insulin and in improving capillary glycemic control in this population.

Key words: gestational diabetes mellitus, insulin, pregnancy, resistance exercise

Gestational diabetes mellitus (GDM) is defined as any degree of glucose intolerance that first occurs or is first diagnosed during pregnancy.1 Adequate glycemic control of patients with GDM is necessary to minimize complications resulting from the disease. In this respect, diet therapy is the first intervention, which, if unsuccessful, should be accompanied by insulin treatment.2 Although effective in reducing the risk of fetal macrosomia,3 insulin therapy does not act on the origin of the problem (ie, increased peripheral resistance to the action of insulin in the second half of gestation).4

Because skeletal muscles represent the main site of insulin resistance observed during pregnancy,5 both the American College of Sports Medicine6 and the American College of Obstetricians and Gynecologists’ recommend exercise as an effective and safe supporting therapy for the treatment of GDM because several lines of evidence have shown the effectiveness of aerobic exercise in reducing the frequency of women using insulin. On the other hand, little is known about the therapeutic application of resistance exercise (RE) to women with GDM. This modality of exercise (RE) consists of the voluntary contraction of skeletal muscle of a certain body segment against some type of external resistance.8 The scientific literature regarding the use of this type of physical activity as a coadjuvant for the treatment of GDM is scarce. To our knowledge, there is only 1 study on this subject conducted by Brankston et al9 in 2004.

Because RE might be an important tool for glycemic control in patients with GDM, the objective of the present study was to evaluate the impact of an RE program with elastic band on insulin requirement and on the adequacy of capillary glycemic control in pregnant patients with GDM. We hypothesized that RE would reduce the number of women who require insulin and would improve glycemic control in these patients.

MATERIALS AND METHODS

A randomized controlled trial was conducted involving patients with GDM who were under prenatal follow-up at the Obstetric Clinic of the University Hospital, University of Sao Paulo School of Medicine, between October 2006 and November 2008 (study period). The study was approved by the Institutional Review Board of the University Hospital, University of Sao Paulo, and written informed consent for participation was obtained from each patient. For data analysis, the patients were randomized into 2 groups: an exercise group (EG), which underwent an RE program until the end of gestation, and a control group (CG), which was not submitted to this program.

Patients with a diagnosis of GDM (made by the 3 hour oral glucose tolerance test [OGTT] after a 100 g glucose overload or by the 2 hour OGTT after a 75 g overload)10 who fulfilled the following criteria were included in the study:

1. Diagnosed with GDM during pregnancy.
2. Undergoing prenatal care at the Obstetric Clinic of the University Hospital, University of Sao Paulo.
3.同意 to participate.
4.同意 to perform exercise sessions.
5.同意 to complete the study protocol.
6.不使用胰岛素治疗。

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sedentary patients according to the International Physical Activity Questionnaire (IPAQ),11 nonsmokers, age range 18–45 years, no physical factor or disease limiting exercise, singleton pregnancy and absence of fetal malformation upon ultrasound, gestational age ranging from 24 to 34 weeks, and no risk factors for preterm delivery. Exclusion criteria were the occurrence of clinical or obstetric complications contraindicating exercise during pregnancy and loss to follow-up. All subjects were instructed not to start any new type of physical activity after the randomization.

On the first visit after the diagnosis of GDM, the patients received instructions regarding capillary glucose monitoring through self-monitoring of fingertip capillary blood glucose 4 times per day (after an overnight fast, 2 h after breakfast, 2 h after lunch, and 2 h after dinner). The objective was to maintain fasting glucose levels of 95 mg/dL or less and postprandial levels of 120 mg/dL or less according to American Diabetes Association (ADA) guidelines.10

All pregnant women with a diagnosis of GDM were systematically evaluated and received diabetic dietary instructions from a nutritionist. The diet was divided into 7 servings, containing 35 kcal/kg ideal weight$^{-1}$/day$^{-1}$, and 300 kcal/day were added in the second and third trimesters of gestation.

After the first medical visit, the patient was informed about the opportunity to participate in this study. Women admitted to the study were randomized using a computer-generated random series produced by a person not related to the protocol.12 The main researcher (M.C.D.B.) questioned the patients with respect to the exercise practice. The use of the elastic band facilitated the adaptation of exercise intensity close to 5 or 6, which corresponds to a “somewhat heavy” exercise perception. The women were advised to maintain an exercise intensity provided to them. The women were advised to undergo the program on 3 nonconsecutive days a week (twice a week at home). The participants were contacted by telephone at least once a week to verify adherence to the program. The other session was performed during the weekly return visit, always under the supervision of the main researcher (M.C.D.B.). On that occasion, EG patients were asked whether they had per-

Exercise intensity was controlled by the women themselves using a perceived exertion scale for RE$^{13}$ provided to them. The women were advised to maintain an exercise intensity close to 5 or 6, which corresponds to a “somewhat heavy” exercise perception. The use of the elastic band facilitated the adaptation of exercise intensity to the level of conditioning of the patients because only its length needed to be adjusted. The main researcher (M.C.D.B.) was responsible for the adjustments, which were always made on the weekly return visits of the patients to the outpatient clinic.

The patients received written guidelines of how to perform each exercise and were instructed to undergo the program on 3 nonconsecutive days a week (twice a week at home). The participants were contacted by telephone at least once a week to verify adherence to the program. The measurement of capillary glycaemia with an Accu-Chek Advantage glucose meter (Roche Diagnostics, Indianapolis, IN). If capillary glucose levels were between 100 and 250 mg/dL, EG patients started the program with a stretching sequence. If capillary glycaemia was below this range, the patients were instructed to do the RE program on the next day to prevent hypoglycaemia. If the values were above this range, the patients were instructed not to undergo RE to prevent the occurrence of ketoacidosis and to contact the responsible obstetrician.

The RE program consisted of a circuit type resistance training,8 elaborated in such a way that the main muscle groups of the patients would be exercised (chest, back, biceps, triceps, deltoïd, quadriceps, thigh, and calf muscles). A circuit series was defined as a sequence of these eight exercises (stations). The women performed 15 repetitions of each exercise (station), with a minimum resting period of 30 seconds and a maximum of 1 minute between each one. In the first and second week of follow-up, the women underwent 2 circuit series, followed by 3 circuit series from the third week of inclusion in the study to the end of gestation.
formed any type of physical activity other than RE. In addition, the adequate execution of RE at the correct intensity was verified. 

The prenatal routine care of CG patients was kept unchanged. The patients attended weekly return outpatient visits and, on that occasion, were questioned whether they had started some type of physical activity. In addition, the patients again responded to the IPAQ. The research visits and care visits were scheduled weekly at the same day for all patients (CG and EG).

The glycemic profile of each patient was determined weekly, and insulin was introduced when more than 30% of the glucose measurements were above the recommended value or when 20–30% of the measurements indicated hyperglycemia and fetal weight was above the 75th percentile. The estimated fetal weight percentile was determined once a month. The initial insulin dose (NPH) was calculated at 0.4 IU/kg⁻¹ per day⁻¹, divided into half at breakfast, one-quarter at lunch, and one-quarter at 10:00 PM. Regular insulin was added at meals to improve the glycemic control if the exclusive use of NPH insulin was not sufficient to maintain the glycemas at adequate levels.

Comparison of the percentage of weeks spent within the target glucose range of at least 80% of weekly measurements considered to be normal for gestation according to ADA guidelines was used as a parameter to evaluate the adequacy of glycemic control. Throughout the follow-up period (time between study inclusion and delivery), the weekly mean of all capillary glucose was calculated for both groups. The mean weekly values of fasting and postprandial capillary blood glucose levels were also obtained. The analysis of the mean of means weekly values previously established was performed for comparison between groups.

**Statistical analysis**

All variables were submitted to comparative analysis using the SPSS for Windows 15.0 program (SPSS, Inc., Chicago, IL). For calculation of the sample size, the objective was to reduce the percent-

| TABLE 1  
<table>
<thead>
<tr>
<th>Maternal characteristics</th>
</tr>
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<tbody>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Maternal age, y</td>
</tr>
<tr>
<td>Gestational age at diagnosis, wks</td>
</tr>
<tr>
<td>Gestational age at first visit, wks</td>
</tr>
<tr>
<td>Pregestational BMI, kg/m²</td>
</tr>
<tr>
<td>First-visit BMI, kg/m²</td>
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<tr>
<td>OGTT, 75 g</td>
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<tr>
<td>Fasting, mg/dL</td>
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<tr>
<td>1 hour, mg/dL</td>
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<tr>
<td>2 hour, mg/dL</td>
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<tr>
<td>OGTT, 100 g</td>
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<tr>
<td>Fasting, mg/dL</td>
</tr>
<tr>
<td>1 hour, mg/dL</td>
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<tr>
<td>2 hour, mg/dL</td>
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<tr>
<td>3 hour</td>
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</tbody>
</table>

Values are the mean ± SD.

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**TABLE 2  
Outcomes**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Control group (n = 32)</th>
<th>Exercise group (n = 32)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Required insulin</td>
<td>18 (56.3%)</td>
<td>7 (21.9%)</td>
<td>.005*</td>
</tr>
<tr>
<td>Amount of insulin required, U/kg</td>
<td>0.49 ± 0.14</td>
<td>0.44 ± 0.11</td>
<td>.401b</td>
</tr>
<tr>
<td>Latency to insulin require m, wks</td>
<td>2.11 ± 1.64</td>
<td>1.85 ± 1.21</td>
<td>.715b</td>
</tr>
<tr>
<td>Mean glucose levels, mg/dL</td>
<td>102.89 ± 7.88</td>
<td>100.30 ± 9.37</td>
<td>.084b</td>
</tr>
<tr>
<td>Percentage of weeks spent within the target glucose range</td>
<td>0.41 ± 0.31</td>
<td>0.63 ± 0.30</td>
<td>.006b</td>
</tr>
</tbody>
</table>

Values are the mean ± SD.

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* Student t test; b At least 80% of weekly capillary glucose measurements within American Diabetes Association guidelines.

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results were submitted to analysis of variance for repeated measures with Huynh-Feldt correction. Mean values of each patient per time of the day (after an overnight fast, 2 h after breakfast, 2 h after lunch, and 2 h after dinner) were used for analysis. Gestational body mass index (BMI) was also compared between groups and periods of gestation using analysis of variance for repeated measures with Huynh-Feldt correction. Bonferroni’s multiple comparisons were performed to determine between which periods glucose levels differed.

The unpaired Student t test was used to compare the mean percentage of time (weeks) spent within the target glucose range during the follow-up period between groups. The existence of an association between groups for the use or not of insulin was evaluated by the χ2 test. Data were analyzed using the intention-to-treat principle. The level of significance was set at 5% for all tests.

**RESULTS**

The sample consisted of 64 patients who were equally divided into the 2 groups. After randomization, 1 patient reported lack of time to perform RE (EG) and another started to use metformin for glycemic control (CG). None of these patients were excluded. An intention-to-treat analysis was chosen to know not just the efficacy of exercise but also the efficacy of the program overall. As shown in Table 1, the groups were similar in terms of the variables measured at the time of inclusion in the study (P > .05). The fasting glucose values in the diagnostic test were 95 mg/dL or greater in 19 of 32 patients in the CG (59.3%), against 18 of 32 patients in the EG (56.3%).

The EG participated in an average of 2.36 ± 0.4 sessions of RE per week. Each RE session lasted 30-40 minutes. The RE program outcomes are shown in Table 2. A significant decrease in the number of patients who required insulin was observed in EG compared with CG. Glycemic control was significantly better in EG compared with CG. In EG, the percentage of weeks spent within the target glucose range (80% of weekly capillary glucose measurements within preestablished guideline values) was significantly higher when compared with CG. No significant difference in mean (± SD) glucose levels was observed between EG and CG. In addition, mean glucose levels measured by the patients at different times of the day throughout the follow-up period were lower in EG compared with CG, but the difference was not significant (Figure 2).

The 2 groups did not differ significantly in terms of the amount of insulin (international units per kilogram) required by the patients or in the time interval (weeks) between inclusion in the study and insulin use (Table 2).

EG patients who used insulin continued to present adequate glycemic control according to the target established for a longer percent period of weeks than control patients who used insulin (EG = 0.40 ± 0.24 vs CG = 0.25 ± 0.23), but the difference was not significant (P = .173). No significant difference in mean glucose levels was observed between patients of the 2 groups who used insulin (CG: 106.83 ± 7.45 vs EG: 109.83 ± 9.04 mg/dL; P = .342). There were no cases of postexercise hypoglycemia or capillary glycemia higher than 250 mg/dL.

The 2 groups were similar in terms of the variables measured at the time of delivery (P > .05) (Table 3). No difference in the frequency of cesarean section was observed between groups (n = 21 of 32 in EG vs n = 24 of 32 in CG; P = .412). Newborn birthweight greater than 4000 g was observed in 1 EG case and 3 CG cases. There were 3 cases of preterm delivery in each group (gestational age at birth ranging from 35 to 36 weeks).

**COMMENT**

The present study permits us to conclude that RE with an elastic band is an effective therapeutic alternative for patients with GDM, reducing the number of patients who will require insulin and improving glycemic control in this population. In the present investigation, a significant decrease in the number of patients who required insulin was observed in the group submitted to RE.

In contrast, Brankston et al did not find a significant difference in the number of women using insulin between the group undergoing RE and the control group (43.8% vs 56.3%; P = .48). These distinct results might be explained by differences in the design of the present...
study and that of Brankston et al.9 The sample size was practically double in the present investigation and different inclusion criteria were used in the 2 studies (different gestational ages at inclusion, exclusion of patients older than 40 years in the study of Brankston et al9).

With respect to the characteristics of the RE program proposed in the 2 studies, there were differences in the choice of exercises to be performed. In addition, in the present study, the RE program was evaluated weekly by the researcher (M.C.D.B.), who monitored the adequacy of the exercise intensity, with adjustment of the length of the elastic band whenever necessary, and the correct execution of the exercises proposed.

Despite the lack of observation of a reduction in the number of women requiring insulin in the group submitted to RE, Brankston et al9 found a significant decrease in the time interval between inclusion in the study and the onset of insulin treatment (control group: 1.11 ± 0.8 weeks; RE group: 3.71 ± 3.1 weeks; P < .05) as well as in the mean (± SD) amount of insulin used at the end of the study by patients of the RE group (control group: 0.48 ± 0.3 IU/kg; RE group: 0.22 ± 0.2 IU/kg; P < .05). In the present study, no differences in the time interval between inclusion in the study and insulin use (P = .715), amount of insulin required (P = .401), capillary mean glucose levels (P = .342), or percentage of weeks spent within the proposed target glucose range were observed between EG and CG patients who used insulin (P = .173).

In the present study, the percentage of days spent within the target glucose range was significantly higher in EG compared with CG (Table 3). Although not statistically significant, the mean blood glucose levels measured by the patients at different times of the day throughout the follow-up period were lower in the EG compared with CG (Figure 2). The mean glucose levels were also lower in the EG compared with CG, but statistically significant (Table 2). Perhaps with a larger number of patients, it was possible to observe a statistically significant difference between groups regarding capillary glucose levels.

With respect to safety, RE does not seem to interfere with pregnancy outcomes. There were no cases of postexercise hypoglycemia or capillary glycermia higher than 250 mg/dL. In addition, no significant differences in BMI, pregnancy weight gain, gestational age at delivery, or number of cesarean sections were observed between the groups studied. The level of adherence to the RE program in pregnancies complicated by GDM was satisfactory, with only 1 patient being lost to follow-up in the present investigation and in the study of Brankston et al.9 The fact that the women can do the exercises at home may have contributed to this result.

The better glycemic control observed in pregnant women with GDM who regularly underwent RE may reduce treatment costs and assist public health policies. An elastic band (with an approximate cost of US $8) was chosen for RE to reduce costs and to permit access to this type of physical activity by the largest possible number of patients.

The present study provided evidence that RE may contribute to the care of patients with GDM. Further well-designed and controlled studies investigating the effects of RE on metabolic control in GDM should compare RE with aerobic exercise and should determine whether the adoption of both types of exercise may confer additional benefits. In addition, the combined action of RE and metformin should be analyzed as well as whether the molecular mechanisms underlying the disease are modified by RE and whether RE is able to prevent the occurrence of GDM as observed for aerobic exercise.19-22

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