Combination of a structured aerobic and resistance exercise improves glycaemic control in pregnant women diagnosed with gestational diabetes mellitus. A randomised controlled trial

Iva Sklempe Kokic[a,*], Marina Ivanisevic[b,c], Gianni Biolo[d], Bostjan Simunic[e], Tomislav Kokic[f,g], Rado Pisot[e]

[a] Department of Health Studies, College of Applied Sciences "Lavoslav Ruzicka" in Vukovar, Zupanijska 50, 32000 Vukovar, Croatia
[b] School of Medicine, University of Zagreb, Salata 3, 10000 Zagreb, Croatia
[c] Department of Obstetrics and Gynecology, University Hospital Centre Zagreb, Petrova 13, 10000 Zagreb, Croatia
[d] Department of Medical, Surgical and Health Sciences, Clinica Medica AOUTS, University of Trieste, Cattinara Hospital, Strada di Fiume, 447-34149 Trieste, Italy
[e] Institute for Kinesiology Research, Science and Research Center of Koper, Garibaldijeva 1, 6000 Koper, Slovenia
[f] Southmead Hospital, North Bristol NHS Trust, Southmead Way, BS10 5NB Bristol, United Kingdom
[g] School of Medicine, Josip Juraj Strossmayer University of Osijek, Osijek, Croatia

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ABSTRACT

Problem: Gestational diabetes mellitus, defined as any carbohydrate intolerance first diagnosed during pregnancy, is associated with a variety of adverse outcomes, both for the mother and her child.
Aim: To investigate the impact of a structured exercise programme which consisted of aerobic and resistance exercises on the parameters of glycaemic control and other health-related outcomes in pregnant women diagnosed with gestational diabetes mellitus.
Methods: Thirty-eight pregnant women diagnosed with gestational diabetes mellitus were randomised to two groups. Experimental group was treated with standard antenatal care for gestational diabetes mellitus, and regular supervised exercise programme plus daily brisk walks of at least 30 min. Control group received only standard antenatal care for gestational diabetes mellitus. The exercise programme was started from the time of diagnosis of diabetes until birth. It was performed two times per week and sessions lasted 50–55 min.
Findings: The experimental group had lower postprandial glucose levels at the end of pregnancy ($P < 0.001$). There was no significant difference between groups in the level of fasting glucose at the end of pregnancy. Also, there were no significant differences in the rate of complications during pregnancy and birth, need for pharmacological therapy, maternal body mass and body fat percentage gains during pregnancy, and neonatal Apgar scores, body mass and ponderal index. Neonatal body mass index was higher in the experimental group ($P = 0.035$).
Conclusion: The structured exercise programme had a beneficial effect on postprandial glucose levels at the end of pregnancy.

Statement of significance

Problem or issue

Gestational diabetes mellitus is associated with an increased rate of perinatal complications and long-term morbidity.

What is already known

Aerobic or resistance exercise programmes from previous trials proved beneficial effects of exercise on the course and outcomes of pregnancy. Combination of aerobic and resistance exercise has synergistic effects in patients with type 2 diabetes.

What this paper adds

Combining aerobic and resistance exercises has beneficial effects on glycaemic control. Furthermore, it is a safe therapeutic strategy for pregnant women with gestational diabetes mellitus.

* Corresponding author.
E-mail address: iskokic@vevu.hr (I. Sklempe Kokic).

1. Introduction

Gestational diabetes mellitus (GDM) is defined as any carbohydrate intolerance first diagnosed during pregnancy.[1] It accounts for 90–95% of all cases of diabetes in pregnancy and is the most common metabolic disorder encountered during pregnancy.[2] The prevalence of GDM is rising, and it is directly related to the prevalence of type 2 diabetes in a given population.[2,3]

GDM is associated with a variety of adverse outcomes, both for the mother and for the fetus. Possible consequences for the mother include an increased rate of perinatal complications, hypertension during pregnancy and preeclampsia. Long term, there is an increased risk of developing type 2 diabetes, metabolic syndrome, obesity, cardiovascular morbidities and recurrent GDM.[2,4] Maternal hyperglycaemia causes an excessive transfer of nutrients – specifically glucose – to the fetus, resulting in fetal hyperinsulinaemia, fetal adiposity, macrosomia and perinatal complications. Long term, these children are also at increased risk of developing obesity, metabolic syndrome, type 2 diabetes and hypertension.[5]

The primary aim of treating GDM is to optimize glycaemic control and improve pregnancy outcomes.[6] Changes in diet and lifestyle are usually recommended as the primary therapeutic strategy to achieve acceptable glycaemic control.[3] If these measures fail to establish adequate glycaemic control within 1–2 weeks, pharmacological therapy is introduced. It is also recommended to continue or initiate exercise at moderate intensity for all pregnant women without contraindications.[2,3]

Exercise is associated with significant, beneficial physiological and metabolic changes and responses to exercise are not different in comparison to the non-pregnant population.[7] Today, physical activity is recommended as a part of antenatal care.[8] Furthermore, exercise leads to improved insulin sensitivity and blood glucose levels in patients with type 2 diabetes.[9] Both aerobic and resistance exercises, especially in combination, have shown beneficial effects in patients with type 2 diabetes.[10] Studies have shown a correlation between higher levels of physical activity before and during early pregnancy with a lower risk of developing GDM.[11]

While the use of exercise in the treatment of type 2 diabetes is supported by plenty of evidence, there is a limited body of evidence exploring the effects of exercise on the course and outcomes of GDM. Only nine prospective trials were found that investigate this subject, seven randomised,[12–18] and two non-randomised.[19,20] Seven of these trials examined the effects of aerobic exercise programmes,[12–14,17–20] whereas only two examined the role of resistance exercises.[15,16] None of the trials examined the effects of combining aerobic and resistance exercises.

Hence, the purpose of this trial was to investigate the health-related effects of implementing a supervised, individualised, structured exercise programme, consisting of aerobic and resistance exercises, on the course and outcomes of GDM. We hypothesized that this exercise programme would improve: glycaemic control, the rate of complications during pregnancy, weight gain and body fat percentage changes during the pregnancy, the rate of complications and mode of birth, and the health status and weight of the newborn.

2. Participants, ethics and methods

2.1. Design and ethics

A randomised controlled trial was conducted between July 2014 and January 2015 comparing an exercise programme with standard antenatal care for GDM. Ethical approval was obtained from the University Hospital Centre Zagreb and the University Hospital Merkur, Zagreb, Croatia and the trial was registered with Clinicaltrials.gov (NCT 02196571). Written, informed consent was obtained from every participant. The trial was conducted in accordance with the Declaration of Helsinki.

2.2. Participants

Participants were recruited by direct contact at two university hospitals in Zagreb, Croatia. Inclusion criteria were: an established diagnosis of gestational diabetes according to the criteria published by the International Association of the Diabetes and Pregnancy Study Groups,[21] aged between 20 and 40. The upper limit for gestational age at the time of inclusion was set at 30 weeks, to allow a minimum exercise period of 6 weeks, until at least the 36th week of pregnancy. Exclusion criteria were: a medical history of diabetes and miscarriages, pharmacological treatment prior to enrolment in the trial, existing comorbidities, and contraindications for exercise as outlined in criteria published by the American College of Obstetricians and Gynecologists (ACOG).[22]

Participants were randomized by block randomisation using a web-based computerized procedure into two groups: experimental and control. The staff involved with the exercise sessions and assessments had no influence on the randomisation procedure. Due to the nature of the study, participants were not blinded. Physicians and laboratory staff were blinded.

2.3. Assessments and measurements

Baseline information taken at the initial interview included: demographic data, medical history including obstetric history, lifestyle habits, physical activity levels and body height and mass at the start of the pregnancy. Pregnant women randomised to the experimental group (EG) were scheduled for their first exercise session. In the 30th, 33rd and 36th week, anthropometric measurements were taken from both groups. Relevant medical documentation was also reviewed in order to assess the course of pregnancy and glycaemic control. Following childbirth, data was gathered on: glycaemic control during the final weeks of pregnancy, the course of birth, neonatal health status and anthropometric information.

All anthropometric measurements were performed by a blinded physiotherapist. These included body mass, arm circumference and skinfold thickness. Body mass was measured using a medical grade digital scale, measuring to the nearest 0.1 kg. This was used to calculate body mass index. Skinfold thickness and arm circumference were measured as recommended by the Manual of International Standards for Anthropometric Assessment.[23] Skinfold thickness was measured using a skinfold caliper (Harpendem Skinfold Caliper, Baty International, Burgess Hill, UK) at the biceps brachii and triceps brachii muscles, and in the subscapular area. Measurements of arm circumference, skinfold thickness and height were fed into the equation by Kannieappan et al.[24] specifically developed and validated for use in pregnant women in order to calculate body fat percentage. Data on neonatal weight, length, Apgar score and health status was extracted from the hospital discharge letter, and used to calculate neonatal body mass index and ponderal index according to the standard equations. Participants' physical activity levels were assessed at baseline and in the 30th and 36th weeks of pregnancy using the Pregnancy Physical Activity Questionnaire.[25]

An oral glucose tolerance test was performed and blood glucose profiles calculated in the medical biochemistry laboratory at the above mentioned hospitals. Analyses were done according to standard operating protocols for the accredited laboratory (International Standards Organization (ISO) 15189 Medical

laboratories – particular requirements for quality and competence) and according to recommendations by the Croatian Chamber of Medical Biochemists. After a diagnosis of GDM was established using the oral glucose tolerance test, all participants had their fasting and postprandial glucose levels measured monthly or bi-monthly for the duration of their pregnancy. Four capillary blood samples were taken: before the first meal in the morning, 2 h after breakfast, 2 h after lunch and 2 h after dinner.

2.4. Intervention

Women in the EG were started on an individualised, structured exercise programme two times per week, along with their standard prenatal care. Participants in this group were also asked to undertake at least 30 min of brisk walking per day. The exercise programme began following an established diagnosis of GDM, and continued throughout the duration of pregnancy. Attendance was recorded at every exercise session and the women were instructed to keep a diary of their daily walks. The minimum total duration of the exercise programme was set at 6 weeks. The minimum acceptable attendance of calculated expected exercise sessions between the time of inclusion in the trial and the 38th week of pregnancy was set at 70%. Women in the CG received standard prenatal care for GDM alone, but were not discouraged from exercising on their own.

Each exercise session lasted for 50–55 min and consisted of aerobic exercise (20 min), resistance exercises (20–25 min), pelvic floor and stretching exercises, and a period of relaxation to end the session (10 min). The aerobic part of the session was performed on treadmill (Axos Runner, Heinz Kettler GmbH, Ense-Parsit, Germany) and aimed to achieve a heart rate within the aerobic zone (65–75% of maximum heart rate), i.e. target values were 13–14 on the Borg Rating of Perceived Exertion scale.[26] Women were free to adjust the velocity and incline of the treadmill to achieve the target intensity. Maternal heart rate was monitored continuously (Mio Alpha, Mio Global, Vancouver, BC, Canada). Baseline heart rate was measured before each session (after 5 min of relaxation), and average values for the aerobic and resistance parts of the session recorded separately. Target heart rate was calculated using Karvonen's formula. Maximum heart rate was determined using the traditional formula 220-age.

Resistance exercises incorporated all major muscle groups, and were performed at each session with the same target values on the Borg Rating of Perceived Exertion scale as for the aerobic part of the session. Six different exercises were performed in three sets of 10–15 repetitions in each set. Three standardized resistance exercise protocols were developed and interchanged. These included exercises for the trunk, and upper and lower limb muscles. They were carried out using body weight, elastic bands (TheraBand, The Hygenic Corporation, Akron, OH, USA) and hand held weights of 0.5 and 1 kg (Aerobic Dumbbels, Heinz Kettler GmbH, Ense-Parsit, Germany). Stretching and pelvic floor exercises were performed at the end of every session, followed by a short period of relaxation to allow a thorough cool-down.

All participants were commenced on medical nutrition therapy recommended for women with GDM. This consisted of 1800 kcal per day: 20% proteins (90 g), 30% fat (60 g) and 50% carbohydrates (225 g), distributed over three main meals and three snacks.

2.5. Statistical methods

Statistical analysis was performed using SPSS 19.0 (IBM, Armonk, NY, USA). Descriptive statistics were calculated for all variables of interest, and included mean value, standard deviation,

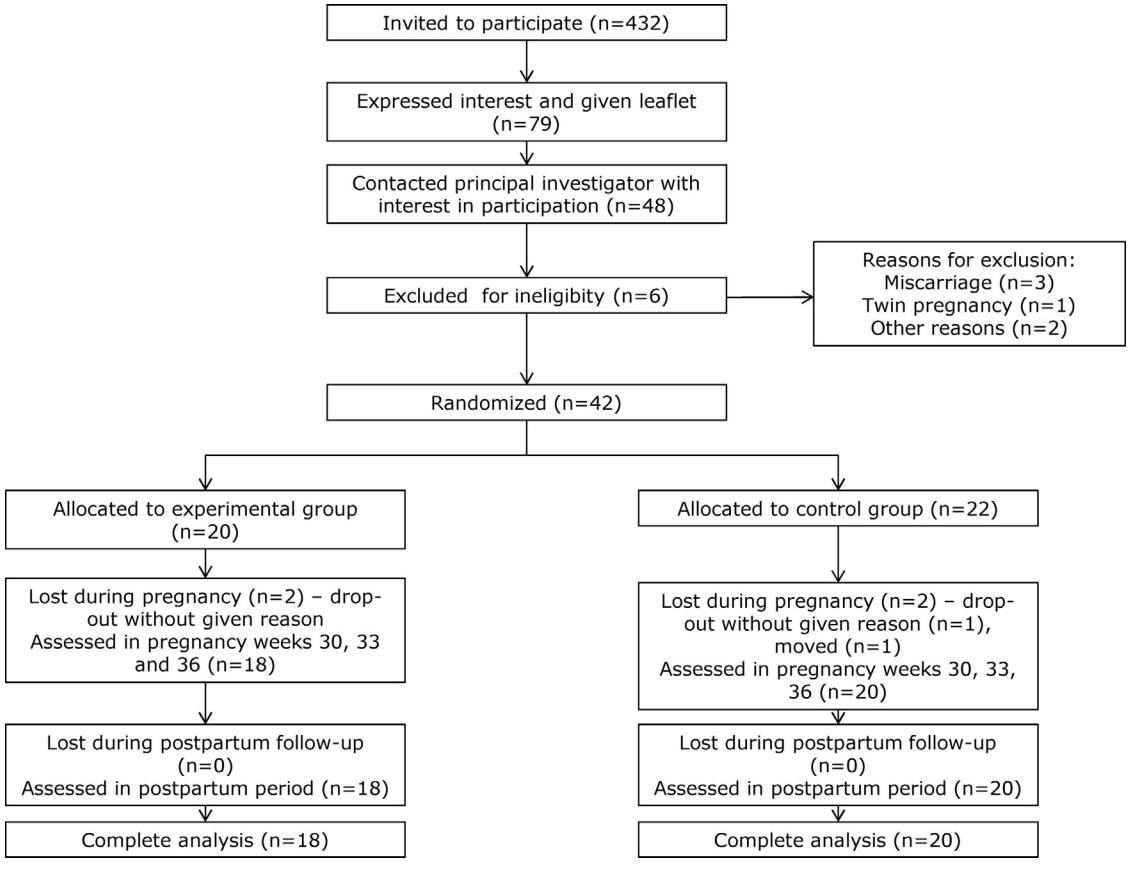

Fig. 1. Flow chart of study participants.

and minimum and maximum values where appropriate. The Shapiro-Wilk test was used to check for normality of data and Levene's test to check for homogeneity of variances. The two-tailed Mann Whitney U without Bonferroni correction test was used to compare baseline participants' characteristics and analyse and compare results between the groups of: the Pregnancy Physical Activity Questionnaire, the rate of complications in pregnancy and during birth, maternal anthropometric measurements at specific time points during pregnancy, neonatal Apgar scores, the rate of neonatal complications and neonatal anthropometric data. An independent sample T-test was used to assess for significant differences in fasting and postprandial glucose levels measured at the end of pregnancy.

Pearson's correlation coefficent (r) was used to calculate the correlation coefficient between main outcomes (fasting and postprandial glucose levels, neonatal anthropometric data) and body mass and gain during specific periods of pregnancy, as well as activity levels as measured by the Pregnancy Physical Activity Questionnaire. Maternal anthropometric measures were correlated with baseline data and levels of physical activity during pregnancy.

The point-biserial correlation coefficient (r_{pbi}) was used to determine the relationship between main outcomes (fasting and postprandial glucose levels, neonatal anthropometric data) and baseline characteristics of the participants, as well as determining the relationship between complications in pregnancy and during birth with maternal anthropometric measures and activity levels as measured by the Pregnancy Physical Activity Questionnaire. The level of significance was set at $P < 0.05$. Cohen's d (d) and effect size (r) were calculated for all outcome variables with the level of significance ≤ 0.05.

3. Results

A total of 42 women diagnosed with GDM were finally enrolled in the trial and randomised to two groups: 20 to the EG and 22 to the CG. Four participants (9.52%) dropped out of the trial, two from the EG (10%) and two from the CG (9.09%) (Fig. 1). The experimental and the control group were well matched, without differences in baseline variables (Table 1) ($P > 0.05$).

A total of 365 exercise sessions were performed during the trial, with an average of 20.28 ± 7.68 sessions performed per subject. The minimum number of exercise sessions performed per subject was 12, and the maximum 34. The average rate of adherence to protocol regarding performed versus planned sessions was high (84.22%), above the 70% threshold set, making the intervention successful for all participants in the EG. We achieved satisfactory exercise intensity in both parts of each exercise session, with an average intensity of $65.06 \pm 4.42\%$ of maximum heart rate, while maintaining target intensity values of 13–14 on the Borg Rating of Perceived Exertion scale. Adherence to daily brisk walking was also well above the 70% threshold, with an average of $95.56 \pm 4.54\%$.

While there was no difference in baseline levels of physical activity between the EG and CG, we found significant differences in the 30th and 36th weeks of pregnancy in favour of EG. The most significant difference – with large effect size – was in the level of sport/exercise activity, with women in the EG recording more sport/exercise activities both during week 30 ($P < 0.001$, $d = 2.37$, $r = 0.76$) and week 36 ($P < 0.001$, $d = 2.41$, $r = 0.77$), compared to the EG. Moderate intensity activities ($P = 0.016$, $d = 0.63$, $r = 0.30$) and transportation activities ($P = 0.024$, $d = 0.82$, $r = 0.38$) were also higher in the EG in the 36th week of pregnancy.

None of the participants from either group required any pharmacological treatment during pregnancy. Final fasting and postprandial glucose values were measured between the 38th and the 40th weeks of pregnancy. While average fasting glucose level was lower in the EG, this was not significant ($P = 0.367$). However, when an average of 3 postprandial glucose levels was calculated, this was significantly lower in the EG, with a large effect size ($P < 0.001$, $d = 1.38$, $r = 0.57$) (Table 2).

Fasting glucose level positively correlated with body mass in the 30th and 36th weeks of pregnancy, ($r = 0.326$, $P = 0.46$; $r = 0.343$,

Table 1
Baseline characteristics for the experimental and control groups.

Variable	EG (N = 18)	CG (N = 20)	P
Maternal age (years; mean ± SD)	32.78 ± 3.83	31.95 ± 4.91	0.478
Body height (m; mean ± SD)	1.67 ± 0.07	1.68 ± 0.06	0.762
Pre-pregnancy body mass (kg; mean ± SD)	68.03 ± 13.65	71.60 ± 15.48	0.515
Pre-pregnancy BMI in (kg/m^2; mean ± SD)	24.39 ± 4.89	25.29 ± 4.65	0.515
Gestational age at diagnosis (week; mean ± SD)	22.44 ± 6.55	20.80 ± 6.05	0.409
Parity (mean ± SD)	0.72 ± 0.83	0.85 ± 0.99	0.806
75 g OGTT (mmol/L; mean ± SD)			
Fasting	5.20 ± 0.39	5.10 ± 0.38	0.515
1 h	9.62 ± 2.14	8.57 ± 2.21	0.219
2 h	7.29 ± 2.26	7.08 ± 1.67	0.696
Education			0.851
Secondary level (N; (%))	7 (38.89)	7 (35.00)	
Tertiary level (N; (%))	11 (61.11)	13 (65.00)	
Pre-pregnancy regular physical activity (N; (%))	9 (50.00)	15 (75.00)	0.196
Positive family history of diabetes mellitus (N; (%))	7 (38.89)	8 (40.00)	0.965
Total activity (MET-h × $week^{-1}$; mean ± SD)	158.22 ± 74.54	126.11 ± 44.63	0.128
Total activity of light intensity and above (≥1.5 METs) (MET-h × $week^{-1}$; mean ± SD)	133.06 ± 74.83	101.75 ± 43.40	0.108
By intensity of activity			
Sedentary (<1.5 METs) (MET-h × $week^{-1}$; mean ± SD)	25.16 ± 13.82	24.36 ± 17.09	0.696
Light (1.5–2.9 METs) (MET-h × $week^{-1}$; mean ± SD)	100.22 ± 46.40	78.44 ± 30.09	0.167
Moderate (3.0–5.9 METs) (MET-h × $week^{-1}$; mean ± SD)	32.69 ± 43.70	22.92 ± 22.35	0.696
Vigorous (≥6.0 METs) (MET-h × $week^{-1}$; mean ± SD)	0.17 ± 0.33	0.40 ± 0.76	0.478
By type of activity			
Household/caregiving (MET-h × $week^{-1}$; mean ± SD)	84.90 ± 71.59	63.58 ± 39.90	0.264
Occupational (MET-h × $week^{-1}$; mean ± SD)	19.41 ± 30.69	6.90 ± 21.25	0.085
Sport/exercise (MET-h × $week^{-1}$; mean ± SD)	3.15 ± 1.98	2.15 ± 2.18	0.061
Transportation activity (MET-h × $week^{-1}$; mean ± SD)	15.65 ± 6.08	17.86 ± 11.60	0.930
Inactivity (MET-h × $week^{-1}$; mean ± SD)	35.10 ± 16.90	35.61 ± 23.53	0.640

BMI – body mass index; CG – control group; EG – experimental group; MET – metabolic equivalent; N – sample size; OGTT – oral glucose tolerance test.

Table 2
Glucose levels at the end of pregnancy.

Variable	EG (N = 18)			CG (N = 20)			P
	Mean ± SD	Min	Max	Mean ± SD	Min	Max	
Fasting glucose level (mmol/L)	4.32 ± 0.26	3.90	4.70	4.44 ± 0.46	3.60	5.30	0.367
Average of 3 postprandial glucose levels (mmol/L)	4.66 ± 0.46	3.67	5.60	5.30 ± 0.47	4.80	6.30	<0.001

CG – control group; EG – experimental group; max – maximum; min – minimum; N – sample size.

P = 0.035 respectively). Conversely, pre-pregnancy regular physical activity negatively correlated with fasting glucose level ($r_{pbi} = -0.429$, P = 0.007). There was a strong negative correlation between sport and exercise levels in the 30th and 36th weeks of pregnancy, (r = −0.527, P = 0.001; r = −0.537, P = 0.001 respectively) and a positive correlation between inactivity levels and postprandial glucose levels (r = 0.369, P = 0.023). We did not find any significant correlation between glycaemic parameters and: duration of intervention, adherence to protocol or the number of exercise sessions attended.

Complications in pregnancy were rare with none occurring in the EG. There were slight differences in body weight, body fat percentage and mass gain during specific time periods of pregnancy between the groups, but none were significant. No significant correlations were identified between mass gain and gain in body fat percentage, and: duration of intervention, adherence to protocol or number of exercise sessions attended.

While the EG had a slightly earlier onset of labour, there was no significant difference between the groups in the timing of birth, with all subjects giving birth between the 38th and 40th week of pregnancy. More labour inductions occurred in the CG, but without statistical significance. There were no significant differences between the groups in: the rates of prolonged labour, instrumental delivery or Cesarean section, Apgar score, neonatal body mass, neonatal length, ponderal index or the rate of neonatal complications (Table 3). There was a significant difference in neonatal body mass index, which was higher in the EG (P = 0.035, d = −0.76, r = −0.35). Percentage of exercise intensity negatively correlated with neonatal body mass (r = −0.481, P = 0.043) and body mass index (r = −0.469, P = 0.05).

4. Discussion

The purpose of this trial was to investigate the impact of a structured programme of aerobic and resistance exercises on the course and outcomes of gestational diabetes mellitus. To the best of our knowledge, this is the first study to investigate the effects of combining aerobic and resistance exercises in pregnant women with GDM, and also the first to investigate the effects of an individualised exercise programme of this type.

Physical activity became the cornerstone of health promotion and disease prevention, not only in the non-pregnant population, but also for pregnant women. All major guidelines on antenatal healthcare recommend exercise in pregnancy for women without contraindications. Furthermore, the American Diabetes Association[2] and ACOG[3] recommend exercise for women with GDM.

We were able to confirm our hypothesis regarding the parameters of glycaemic control, but only partially. Fasting glucose levels at the end of pregnancy – measured between the 38th and the 40th weeks – were lower in the EG, but the difference was not significant (P = 0.367). This result is similar to that achieved by Callaway et al.[27] who observed that fasting glucose levels were lower in their EG in the 28th week of pregnancy, but not in the 36th week. Our trial found that, conversely, when an average of 3 postprandial measurements was calculated, this was lower in the EG, with statistical significance and a large effect size (P < 0.001, d = 1.38, r = 0.57). This is in accordance with the results from another trial,[18] where overall postprandial glucose concentration was lower in the EG compared to the CG (P = 0.046). Likewise, a further four trials[12,15,17,20] previously reported a significant decrease in postprandial glucose levels following the implementation of their exercise interventions. It is likely that this is the outcome of improved peripheral insulin sensitivity resulting from regular exercise.

The average weight gain in pregnancy is quoted as being 12.5 kg[28] with a proposed target weight gain for healthy women with a normal body mass of between 11 and 16 kg. Overweight women should not gain more than 11 kg during pregnancy, and obese women not more than 9 kg.[29] Our EG would be classified as being in the normal weight category, with an average body mass index of 24.39 ± 4.89 kg/m^2. Our CG was slightly overweight (body mass index = 25.29 ± 4.65 kg/m^2), but the difference between the groups was not significant (P = 0.515). There were no differences in weight gain or fat mass gain during pregnancy between the pregnant women who participated in our structured exercise programme and those who received only standard antenatal care. De Barros et al.[16] also failed to detect any significant changes in body mass index at birth and body mass gained during pregnancy between the exercising and non-exercising groups. Conversely, Artal et al.[19] observed a decrease in the total body mass gained

Table 3
Obstetric and neonatal outcomes.

Variable	EG (N = 18) Mean ± SD	CG (N = 20) Mean ± SD	P
Week of birth	38.89 ± 0.90	39.45 ± 0.60	0.063
Prolonged labour (N (%))	1 (5.56)	2 (10)	0.633
Labour induction (N (%))	3 (11.11)	7 (35)	0.346
Instrumental delivery (N (%))	1 (5.56)	0 (0)	0.784
Caesarean section (N (%))	5 (27.78)	5 (25)	0.696
Apgar 1 min (mean ± SD)	9.89 ± 0.47	9.80 ± 0.70	0.828
Apgar 5 min (mean ± SD)	10 ± 0.00	10 ± 0.00	1.000
Neonatal hypoglycaemia (N(%))	0 (0)	0 (0)	1.000
Other neonatal complications (N(%)) (hyperbilirubinaemia)	0 (0)	1 (5)	0.806
Neonatal body mass (g)	3514.45 ± 413.57	3377.00 ± 494.27	0.393
Neonatal length (cm)	50.11 ± 2.25	50.25 ± 2.51	0.851
Neonatal PI (kg/m^3)	2.66 ± 0.63	2.65 ± 0.16	0.093
Neonatal BMI (kg/m^2)	13.96 ± 0.97	13.21 ± 1.01	0.035

BMI – body mass index; CG – control group; EG – experimental group; N – sample size; PI – ponderal index.

($P < 0.01$) as well as in the average body mass gained per week ($P < 0.05$) in the EG.

No complications were encountered in the EG during pregnancy, and there were no significant differences between the groups. There were two cases of pregnancy-induced hypertension in the CG, one of which progressed to preeclampsia. The implementation of this exercise programme did not reduce the rate of complications during birth. We observed excellent Apgar scores in both groups. Exercise in pregnancy did not cause any adverse effects on the fetus or neonate, in accordance with previous findings.[30] There were no significant differences between the groups in neonatal weight, length and PI. Contrary to our expectations, however, neonatal body mass index was slightly higher in the experimental group ($P = 0.035$). Still, neonatal body mass in both groups was well within healthy limits. These findings are similar to those of previous trials where no significant difference was observed in neonatal body mass between exercising and non exercising women diagnosed with gestational diabetes mellitus.[13,14,16,19,20]

The main limitation of this study was the small sample size. According to the new criteria, however, there were no exact data on the prevalence of gestational diabetes mellitus in the Croatian population, preventing the calculation of an ideal sample size. It is, therefore, possible that the studied population is not representative of the general population affected by GDM. Participation in this trial was on a voluntary basis, thereby allowing the possibility for a selection bias towards those women with more awareness of their condition and those more committed to adhering to lifestyle changes. Another limitation of this study was the failure to track and analyse dietary intake. All participants, however, received the same medical nutrition intervention.

5. Conclusion

In conclusion, we successfully proved that the combination of aerobic and resistance exercises offers significant benefits for women with gestational diabetes mellitus. Specific guidelines for the optimal type, frequency, duration and intensity of exercise should be developed and incorporated into the general guidelines for the treatment of GDM.

Conflicts of interest

None.

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Author contributions

I. S. K. contributed to the study concept, protocol development, data collection, statistical analysis, and writing of the manuscript. M. I. contributed to the study concept, protocol development, data collection, and review and editing of the manuscript. G. B. and R. P. contributed to the study concept, protocol development, and review and editing of the manuscript. T. K. contributed to the protocol development, data collection, and editing of the manuscript. B. S. contributed to the protocol development, statistical analysis, and review of the manuscript. I. S. K. is the guarantor of this study, and as such, had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors have approved the final article.

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