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A concurrent prenatal exercise program increases neonatal and placental weight and shortens labor: The GESTAFIT project

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Objective: To explore the influence of a supervised concurrent exercise-training program during pregnancy on maternal and neonatal birth-related outcomes and type of birth.

Methods: One hundred and fifty-nine Caucasian pregnant women from the GESTAFIT project participated in this quasi-experimental study and were allocated into control [(n = 86), (age 33.1 ± 4.8 years old, BMI 24.8 ± 4.1 kg/m^2)] or exercise group [(n = 50) (age 33.1 ± 4.1 years old, BMI: 24.7 ± 4.1 kg/m^2)]. The exercise group followed a 60-min 3 days/week concurrent (aerobic and strength) training program from the 17th gestational week until birth. Maternal and neonatal birth-related outcomes (i.e., gestational age at birth, duration of labor, placental and neonatal weight and type of birth) were collected from obstetric medical records. Umbilical arterial and venous blood gas analysis were assessed after birth.

Results: The exercise group increased average duration of the first stage of labor [between-group differences (B): 80.8 min, 95% confidence interval (CI), 4.18, 157.31, p = 0.03] and decreased duration of the second stage of labor [between-group differences (B): 29.8 min, 95% CI: −55.5, −4.17, p = 0.02] compared to the control group. The exercise group showed greater placental [between-group differences (B): 53.3 g (95% CI: 9.99, 96.7, p = 0.01)] and neonatal [between-group differences (B): 161.8 g (95% CI: 9.81, 313.8, p = 0.033)] weight compared to the control group. No differences between groups were found regarding type of birth (p > 0.05).

Conclusions: A concurrent and supervised physical exercise program during pregnancy is safe and could promote better maternal and neonatal birth-related outcomes. More studies are needed to clarify the mechanisms by which physical exercise increases neonatal and placenta weight.

KEYWORDS
aerobic exercise, cesarean section, parturition, strength training

1 | INTRODUCTION

Physical exercise is any type of planned and structured physical activity, produced by skeletal muscle contractions that results in energy expenditure.[1] The cardiometabolic adaptations that occur during pregnancy provide a wide margin of safety for physical training in women without contraindications.[2] Despite the potential benefits associated with physical exercise during pregnancy, evidence suggests that the percentage of pregnant women who train in this period remains low.[3] Regarding maternal health-related outcomes, exercising during pregnancy has been previously related to adequate weight gain,[4] lower risk of gestational diabetes,[5] and future chronic diseases.[6] In addition, physical exercise could positively influence birth-related outcomes, providing a shorter duration of labor[7] and lower cesarean rates.[8] Regarding the effects of maternal exercise on neonatal birth-related outcomes, such as birthweight, results until date are still contradictory. There are several studies reporting lower or greater birthweight[9,10] or even no effect[11] on birthweight in babies whose mothers exercised during gestation. These differences could be explained by type and intensity of the exercise training program performed. In fact, exercise training program not including muscle strengthening does not seem to exert an effect on fetal weight.[12] Our group previously described that greater maternal upper-body muscle strength (which is usually increased in pregnant women who train) was associated with greater neonatal birthweight.[13] Of note, birthweight is an important health status factor in both the neonatal period and childhood. Birthweight is also often related to placental weight.[14] The placenta is the main organ of attachment and communication between the fetus and the mother. This makes the placenta a sensitive organ to external stimuli and fundamental for the fetal development. The placenta also has endocrine functions and plays a fundamental role in the necessary gas exchange for fetal viability; this is especially important during labor.[15] To date, human studies are still scarce or show contradictory results regarding the effects of maternal physical exercise on different birth-related outcomes. Moreover, most of the exercise training programs developed for pregnant women have focused exclusively on aerobic or strength training. For this reason, we aimed to analyze the influence of a supervised concurrent (aerobic and strength) exercise-training program from the 17th gestational week (g.w.) until birth on maternal and neonatal birth-related outcomes and type of birth.

2 | METHODS

2.1 | Study population

The complete methodology of the GESTAFIT project has been previously published (registration number: NCT02582567).[16]

A total of 384 women were contacted at "San Cecilio" and "Virgen de las Nieves" University Hospitals, in Granada (southern Spain) at their first gynecological visit at the 12th g.w. Recruitment was performed by the research team in three different waves. From the initially interested participants, 159 met the inclusion–exclusion criteria (Table S1) and signed the consent after being correctly informed about the study aims, methodology, and procedures. The GESTAFIT study was approved by the Clinical Research Ethics Committee of Granada, Government of Andalusia, Spain (code: GESFIT-0448-N-15, approved on May 19, 2015).

2.2 | Randomization and blinding

Initially, the GESTAFIT project was designed as a randomized control trial. However, randomization was not possible in all waves due to some difficulties related to the recruitment of overweight-obese pregnant women, and problems regarding the adherence of women in the control group. This represents a common methodological and ethical barrier, and it is frequent in antenatal exercise.[17] Therefore, women were allocated either to an exercise or a control group depending on their personal preference, convenience to attend the exercise training program, and the wave they were recruited for.

2.3 | Procedures

Participants were assessed twice (2 days each time) during the study. The first evaluation was carried out at the gestational weeks 16–17 g.w. (before the intervention started). Sociodemographic and clinical characteristics were self-reported through a questionnaire (anamnesis) guided by a member of the research team. In the same day, body weight, height, and physical fitness were assessed. Each participant was given an accelerometer and had to wear it for nine consecutive days until second day of evaluation. Physical fitness was assessed again during the second assessment, conducted at the 33–34th g.w. Obstetric and gynecological history was collected through the "Pregnancy Health Document." After birth, obstetric outcomes were collected from digital medical records. Sampling of the umbilical cord blood occurred immediately after birth.

2.4 | Exercise group

Pregnant women in the exercise group participated in a concurrent-training program from the 17th g.w. until birth (3 days/week, and 60 min/session) consisting in a combination of aerobic and resistance exercises of moderate-to-vigorous intensity. This exercise protocol was designed following the American College of Obstetricians and Gynecologists guidelines,[18] and it has been further detailed elsewhere.[19] The exercise group started with three informative and movement learning sessions. In this way, fundamental basic movement patterns were taught (hip dominant, knee dominant, pull and push movements), and theoretical explanations were provided to the participants. Subsequently, the main exercise training phase lasted from the 17th to the 34th g.w. and was focused on improving or maintaining physical fitness. From the 34th g.w. until birth, pelvic mobilization exercises were introduced to prepare participants for birth. Each exercise session began with a 10-min warm-up including walking, mobility and activation exercises. The main part of the first and third sessions of the week consisted of two resistance-exercise circuits lasting 40 min in total. Each circuit consisted of five exercises and three repetitions (40 s work/20 s rest), alternating with cardiovascular blocks. The second session of the week was focused on aerobic training through dancing, proprioceptive and coordinative circuits and walking intervals. The sessions finished with a 10-min cool-down period of stretching, breathing, relaxation exercises, and myofascial relief.[19] Attendance to each training session was recorded to assess compliance with the exercise program. Only pregnant women who attended at least to 75% of the exercise training sessions were included in the per-protocol analyses.

2.5 | Control group

Pregnant women in the control group did not take part in the exercise training program, and they just were requested to continue with their usual daily activities. In addition, the research team gave them seven workshops focused on different maternity topics, such as healthy lifestyle habits, breastfeeding, and sexuality. These workshops were also offered to participants in the exercise group.

2.6 | Measured outcomes

2.6.1 | Sociodemographic and clinical data

Sociodemographic characteristics (such as age, cohabitation, educational level, and smoking habit), reproductive history, and clinical data were gathered by means of a self-reported survey. Researchers explained how to complete this questionnaire properly.

2.6.2 | Body composition

At the 16–17th g.w. assessment, maternal height was measured with a stadiometer (Seca22, Hamburg, Germany) and weight was measured with a scale (InBody R20, Biospace, Seoul, Korea). Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared. Weight status groups were based on standard clinical definitions for BMI (normal-weight: 18.5–24.9 kg/m^2 and overweight/obese: ≥25.0 kg/m^2).

2.6.3 | Previous obstetric history

The "Pregnancy Health Document" is given to all pregnant women by the Andalusian regional government, and it contains obstetric and medical information. The research team had access to this medical and obstetric records only for the purpose of the study. In this way, information regarding parity, gravidity, course of previous pregnancies, births, and gynecological antecedents was obtained. Gestational age was calculated by the date of last menstruation corrected for cycles of 28 days and subsequently corrected by ultrasound, if needed.

2.6.4 | Physical fitness

Muscular strength

Hand grip strength was measured at the 16–17th g.w and at the 33–34th g.w. with digital dynamometry (TKK 5101 Grip-D; Takey, Tokyo, Japan), after adjusting by the hand size for an optimal grip, following a protocol described for women.[20] The test was performed twice with both hands, with a rest of 30 s and alternating hands. The final value was calculated as a mean of the best value from each hand.

Cardiorespiratory fitness

Maximal oxygen intake (VO2max) was estimated (ml/(kg·min)) at the 16–17th g.w and at the 33–34th g.w. through the Bruce treadmill protocol, a submaximal, incremental, multistage, continuous treadmill test. The test consists of progressive increments in the workload and velocity every 3 min to determine limits of maximal exertion. This test has been previously used and shown to be safe in pregnant women.[21]

2.6.5 | Sedentary time and physical activity levels

Sedentary time (ST) and physical activity (PA) levels were objectively assessed with triaxial accelerometry (ActiGraph GT3X+, Pensacola, Florida, US), carried by participants on their hips 24 h per day for 9 consecutive days at the 16th g.w. Detailed information about the accelerometer assessment has been previously published.[22] Data download, reduction, cleaning, and analyses were performed using ActiGraph software (ActiLife v. 6.13.3).

2.6.6 | Birth outcomes

After birth, information regarding gestational age at birth, type of labor (i.e., eutocic, instrumental, or cesarean section), type of analgesia employed (if any), oxytocin administration during labor, duration of the first and second stages of labor, birthweight, and neonatal sex were obtained from the perinatal obstetric records (partogram).

Length of labor
First stage of labor was defined as the period comprising a cervical dilation of 4 cm or more with regular uterine contractions until full dilation, which was defined by a dilation of the cervix of 10 cm.[23] The second stage of labor or expulsive period was defined as time from fully dilated cervix to complete delivery of the fetus.[23] The total duration of the labor was calculated as the sum of the first and second stages of labor.

Umbilical cord blood gas
Samples of arterial and venous blood from the umbilical cord were collected before delivery of the placenta to assess pH, partial pressure of carbon dioxide (PCO2), partial pressure of oxygen (PO2), and oxygen saturation using a blood analyzer (GEM Premier 4000, Bedford, MA, USA). Double clamping of the umbilical cord was performed by a trained midwife between the first and third minutes of the new-born's life, with a minimum distance between both clamps of 10 cm. For extraction of blood, pre-heparinized 1 ml syringe was used. Gas analysis was carried out at the time of extraction at room temperature.

Placental weight
The placenta was collected immediately after birth, and all placental surface clots were removed. The amnion was cut from the basal area, and the umbilical cord was completely cut. Subsequently, placental weighted was recorded using a 3.200 kg Precision Gram Scale (Ohaus Compass TM, USA).

2.7 | Statistical analysis

Descriptive statistics (mean ± standard deviation for quantitative variables and number of women [%] for categorical variables) analysis were performed to show sociodemographic and clinical characteristics of the study sample. Differences in baseline values between groups were assessed via Student's *t*-test for continuous variables and the chi-square test for categorical variables. As previously designed,[16] only women who attended at least 75% the exercise training program were included in the per-protocol analyses. Moreover, data from three preterm births were removed from the analyses. Subsequently, linear regression analyses were employed to study differences in maternal and neonatal birth-related outcomes between control and exercise groups. Birth-related outcomes were included in the linear regression as dependent variables and the group (control or exercise) as independent variable. After considering relevant confounders suggested by previous literature and which had a significant influence the dependent variable (i.e., meaningful change in the coefficient B of the independent variable when added) were included in the analyses. Model 1 was adjusted for age, parity, maternal BMI at the 16th g.w., epidural analgesia (except for neonatal and placenta birthweight), ST, total PA[22] and VO2max at the 16th g.w. Duration of first and second stages and total duration of labor were additionally adjusted for oxytocin administration and birthweight.[7,24] Birthweight and placental weight were additionally adjusted for gestational age, smoking status, and baseline values of muscular strength.[13] Umbilical cord blood gas was additionally adjusted for baselines values of cardiorespiratory fitness.[13]

After multiple imputation of the data, the abovementioned statistical analyses were repeated on an intention-to-treat basis to assess more realistically effects of the intervention program (Table S2).

3 | RESULTS

Flow chart of the study participants is shown in Figure S1. A total of 136 pregnant women divided into control (n = 86) (age 33.3 ± 4.8 years old, BMI: 24.8 ± 4.1 kg/m^2)

TABLE 1 Baseline sociodemographic and clinical characteristics of the study participants (n = 136)

Maternal outcomes	All women (n = 136)	Control group (n = 86)	Exercise Group (n = 50)	p
Age, years	33.2 (4.6)	33.3 (4.8)	33.1 (4.1)	0.84
16th gestational week				
Body mass index (kg/m²)	24.8 (4.1)	24.8 (4.1)	24.7 (4.1)	0.92
Upper-body muscular strength (kg)	27.2 (4.3)	27.3 (4.8)	26.8 (3.3)	0.51
VO2max ml/(kg·min)	22 (5.4)	21.4 (5.1)	22.7 (5.8)	0.22
Sedentary time (min/week)	3583.2 (671.1)	3486.5 (707)	3726.1 (592.6)	0.05
Total physical activity (min/week)	2948.9 (637.3)	3028.4 (659.3)	2920.5 (604.3)	0.36
Smoking status, n (%)	11 (8.1)	9 (11.8)	1 (2)	0.06
Living with partner, n (%)	134 (97.8)	84 (97.7)	50 (100)	0.39
Educational status, n (%)				0.96
Primary or high-school	28 (20.6)	19 (22.1)	9 (18)	
Specialized training	23 (16.9)	14 (16.3)	9 (18)	
University degree	85 (62.5)	53 (61.6)	32 (64)	
Type of birth, n (%)				0.46
Eutocic	70 (58.8)	41 (57.7)	30 (61.2)	
Instrumental vacuum/forceps	19 (15.9)	9 (12.7)	10 (19.4)	
Cesarean section (all causes)	30 (25.2)	21 (29.6)	9 (18.4)	
Cesarean section due to loss of fetal well-being	8 (6.7)	8 (11.3)	0 (0)	
Birth place, n (%)				0.63
Public Hospital	117 (94.4)	70 (94.6)	47 (94)	
Private Hospital	6 (4.8)	3 (4.1)	3 (6)	
Home	1 (0.8)	1 (1.4)	0 (0)	
Parity, n (%)				
Nulliparous	86 (62.8)	51 (58.6)	35 (70)	0.46
Multiparous	51 (37.2)	36 (41.4)	15 (30)	
Epidural analgesia, n (%)	76 (66.7)	41 (61.2)	35 (74.5)	0.08
Oxytocin administration, n (%)	34 (30.9)	20 (32.3)	14 (29.2)	0.54
Duration of first stage of labor, minutes	220.5 (154.7)	202.21 (137.2)	241.9 (172.4)	0.26
Duration of second stage of labor, minutes	94.4 (67)	95.7 (69.2)	93 (65.4)	0.93
Total duration of labor, minutes	316.9 (191.8)	297.72 (181.6)	337.8 (202.9)	0.37
Neonatal outcomes				
Sex (female), n (%)	60 (50.8)	36 (51.4)	24 (50)	
Gestational age at birth, weeks	39.5 (1.3)	39.4 (1.5)	39.7 (1.1)	0.22
Birthweight, grams	3280.7 (490.0)	3218.9 (545.9)	3375.5 (378.9)	0.06
Placental weight, grams	571.9 (100.8)	550.74 (84.3)	590.26 (110.9)	0.07
Apgar Test 1 min	8.6 (1.1)	8.5 (1.1)	8.6 (0.9)	0.72
Apgar Test 5 min	9.6 (0.7)	9.5 (0.7)	9.7 (0.6)	0.41
Umbilical Cord blood Gas				
Arterial pH	7.2 (0.07)	7.2 (0.08)	7.2 (0.06)	0.17
Arterial Partial Pressure CO2 (mmHg)	52.1 (10.4)	52.4 (11.1)	51.7 (9.6)	0.76
Arterial Partial Pressure O2 (mmHg)	18.9 (8.5)	19.9 (8.7)	19.9 (8.4)	0.31
Arterial O2 saturation (%)	33.3 (21.4)	39.9 (21.8)	32.7 (21.1)	0.81
Venous pH	7.3 (0.07)	7.3 (0.08)	7.3 (0.06)	0.79

(Continues)

TABLE 1 (Continued)

Maternal outcomes	All women ($n = 136$)	Control group ($n = 86$)	Exercise Group ($n = 50$)	p
Venous Partial Pressure CO2 (mmHg)	39.1 (7.4)	39.5 (8.1)	38.5 (6.7)	0.53
Venous Partial Pressure O2, (mmHg)	26.1 (8.7)	27.1 (9.8)	25.1 (7.2)	0.29
Venous O2 saturation (%)	55.9 (18.1)	54.8 (19.4)	57.1 (16.7)	0.57

Note: Values shown as mean (SD, standard deviation) unless otherwise indicated.

Abbreviations: BMI, body mass index; CRF, cardiorespiratory fitness; CO2, carbon dioxide; O2, oxygen.

and exercise groups ($n = 50$) (age 33.1 ± 4.1 years old, BMI: 24.7 ± 4.1 kg/m^2) were included in the present analysis. Sociodemographic and clinical characteristics of the study participants are shown in Table 1. Roughly, most women lived with their partners (97.8%) and had University studies (62.5%). Almost 30% of births in the control group occurred by cesarean section compared to 19% of cesarean sections in the exercise group. No differences between groups were found in any of the variables in the baseline data (all, $p \geq 0.05$).

The effects of the concurrent exercise training program on maternal and neonatal birth-related outcomes are shown in Table 2. In the unadjusted model, no significant differences between groups were found in maternal and neonatal birth-related outcomes (all, $p > 0.05$). In Model 1, the exercise group increased the average duration of first stage of labor by 81 min (95% CI: 4.18, 157.3, $p = 0.037$) and decreased 30 min the duration of second stage of labor (95% CI: −55.55, −4.17, $p = 0.02$) compared to the control group. Nevertheless, no significant differences between groups were found in total duration of labor ($p = 0.196$). Finally, the exercise group showed greater placental weight [between-group differences (B): 53.3 g (95% CI: 9.99, 96.7, $p = 0.017$)] and greater neonatal birthweight [between-group differences (B): 161.8 g (95% CI: 9.81, 313.8, $p = 0.03$)] compared to the control group. The effects of the concurrent exercise training program on type of birth were explored using the chi-square test (data not shown). No statistically significant differences between both groups were found in relation to type of birth ($p > 0.05$). Intention-to-treat analyses have been added to Tables S2. Considering that some authors do not recommend to perform imputations when more than 20% of cases are missing,[25] we have not considered these data for the discussion. The first stage of labor was 72.33 min longer on average in the intervention group in the adjusted model ($p = 0.03$). However, there was no difference in the duration of the second stage of labor between both groups. The intervention group showed greater placental and neonatal weights in both models (all, $p < 0.05$).

4 | DISCUSSION

The major findings of this study indicate that the exercise group had a longer first stage and shorter second stage of labor; and greater placental and neonatal weight compared to the control group. No differences between groups were found in the remaining birth-related outcomes studied neither in the type of birth. However, it is noteworthy that cesarean sections due to suspected loss of fetal wellbeing were only necessary in the control group.

Although the exercise program had no effect on gestational age at birth, our results could be interpreted positively, since there were only three preterm births (at the 34th, 35th, and 36th g.w.) which belonged to women in the control group. In epidemiological studies, approximately 10% of births take place prematurely[26] and the shortening of gestation time has been described as a risk factor for problems related to adaptation to the extra uterine environment. To note, neonates who are born prematurely are more likely to develop chronic kidney diseases, neurodevelopmental deficits, increased blood pressure and cardiac pathologies, reduced sensitivity to insulin and chronic obstructions of the airways, among others.[27] In this sense, exercise during pregnancy has been described as a protective factor for preterm birth,[28] which concurs with the present findings. Moreover, Huang et al.[29] also described a lower risk of preterm birth in women who exercised at moderate intensity during pregnancy. However, other studies found no association between exercise and gestational age at birth.[30]

Regarding duration of labor, our results agree with those described by Sanda et al.,[31] finding a longer first stage of labor in women who took part in a physical exercise program during pregnancy (cardiovascular and strength exercises) twice a week. In contrast, Perales et al.[24] found that pregnant women from the intervention group (aerobic dance and strength exercises) had a shorter first stage of labor. However, this relationship disappeared after adjusting for confounders. Similarly, Salvensen et al.[32] found no differences in the total duration of labor between pregnant women who performed a

TABLE 2 Per-protocol basis analyses showing the effect of the concurrent exercise training program (control or exercise group) on maternal and neonatal birth outcomes

	Mean difference (SE)	Unadjusted model					Model 1				
		β	B	95% CI		*p*	*β*	B	95% CI		*p*
Maternal outcomes											
Gestational age at birth, weeks (*n* = 68 vs 49)	−0.11 (0.21)	0.11	0.11	−0.31	0.54	0.59	0.02	0.04	−0.46	0.55	0.84
Duration of first stage of labor, minutes[a] (*n* = 41 vs 36)	−42.11 (35.41)	0.13	42.11	−28.43	112.66	0.23	0.24	80.73	4.18	157.3	0.03
Duration of second stage of labor, minutes[a] (*n* = 42 vs 39)	2.78 (14.96)	−0.002	−2.78	−32.62	27.05	0.85	−0.23	−29.86	−55.55	−4.17	0.02
Total duration of labor, minutes[a] (*n* = 38 vs 36)	−40.83 (44.98)	40.15	40.83	−130.77	49.11	0.37	0.129	53.04	−31.17	137.26	0.21
Neonatal outcomes											
Placental weight, grams (*n* = 40 vs 46)[b]	−39.52 (21.1)	0.19	39.52	−3.24	82.28	0.07	0.286	53.32	9.99	96.66	0.01
Birthweight, grams (*n* = 67 vs 49)[b]	−98.64 (78.72)	0.11	98.64	−62.47	259.76	0.22	0.187	161.81	9.81	313.8	0.03
Apgar test 1 min (*n* = 65 vs 48)	−0.09 (0.2)	0.04	0.09	−0.31	0.49	0.72	0.02	0.003	−0.38	0.39	0.97
Apgar test 5 min (*n* = 65 vs 48)	−0.13 (0.13)	0.09	0.13	−0.01	0.41	0.335	0.13	0.21	−0.15	0.58	0.24
Cord blood arterial pH (*n* = 46 vs 37)	0.02 (0.01)	−0.12	−0.02	−0.05	0.01	0.17	−0.28	−0.02	−0.06	0.21	0.35
Cord blood arterial PCO2 (*n* = 42 vs 35)	1.3 (2.4)	−0.01	−1.3	−6.1	3.5	0.59	−0.06	−1.33	−7.46	4.79	0.66
Cod blood arterial PO2 (*n* = 37 vs 36)	1.26 (1.95)	−0.07	−1.26	−5.16	2.62	0.51	−0.04	−0.77	−6.42	4.87	0.78
Cord blood arterial O2 saturation (*n* = 40 vs 34)	−0.7 (4.8)	0.02	0.07	−8.94	10.35	0.88	0.003	0.138	−12.1	12.38	0.98
Cord blood venous pH (*n* = 50 vs 46)	−0.007 (0.01)	−0.08	0.00	−0.02	0.03	0.78	0.006	0.001	−0.03	0.034	0.96
Cord blood venous PCO2 (*n* = 46 vs 45)	1.2 (1.58)	−0.06	−1.2	−4.35	1.94	0.53	0.06	0.81	−2.94	4.56	0.66
Cord blood venous O2 (*n* = 41 vs 42)	0.48 (1.47)	−0.03	−0.48	−3.62	2.66	0.76	0.13	0.17	−32.8	0.67	0.49
Cord blood venous O2 saturation (*n* = 40 vs 341)	−3.87 (3.99)	0.11	3.87	−3.89	11.65	0.32	0.001	0.022	−10.22	10.26	0.99

Abbreviations: SE, standard error; O2, Oxygen; PO2, partial pressure of oxygen; PCO2, partial pressure of carbon dioxide.

Note: Results show mean difference between control and exercise groups regarding maternal and neonatal birth outcomes (standard error). Model 1 was adjusted for age, parity, maternal body mass index, epidural analgesia, sedentary time, and total physical activity at the 16th gestational week.

[a]Model additionally adjusted for oxytocin administration and birthweight.

[b]Model additionally adjusted for gestational age, smoking status and muscular strength at the 16th gestational week. Umbilical cord blood gas was additionally adjusted for baselines values of cardiorespiratory fitness. β, standardized beta. Only women with available data and participants exercise group who attended ≥75% of the exercise sessions were included. Sample sizes shown correspond to the adjusted model (Model 1).

concurrent exercise program and women in the control group. The methodological differences between exercise-training programs and the differences in the definitions of the stages of labor do not allow a reliable comparison. We explored the effect of the exercise training program on total duration of labor (calculated as the sum of first and second stages of labor), and there were no differences between groups. Therefore, it seems that, although cervical dilation time was longer, the total time of labor was not affected by our intervention program. For this reason, the shortening of the second stage of labor is a positive finding, since the prolongation of this stage is related to birth-related adverse outcomes such as greater instrumental deliveries and cesarean sections, shoulder dystocia, postpartum hemorrhage, and low scores in the Apgar test, among others.[33]

Interestingly, placentas and neonates of mothers in the exercise group weighed more. Performing moderate-intensity physical exercise regularly during pregnancy has been shown to increase maternal plasma volume, and vascularity of the intervillous space.[34] A previous study suggests that maternal exercise may modify the expression of important genes for offspring development, such as sodium-coupled neutral amino acid transporter 2,[35] and fatty acid transport protein 4.[35] Nevertheless, physical exercise at a more vigorous intensity or with more frequent training sessions could have the opposite effect, decreasing the placental size.[36] In this sense, placental weight is positively associated with birthweight, so both findings are correlated ($r = 0.539$, $p < 0.01$, data not shown). Regarding birthweight, only 5 neonates presented macrosomia (more than 4000 g of weight[37]), three of them belonged to the control group and two of them to the intervention group, but none of those mothers were diabetic. Therefore, our exercise program increased fetal weight, without increasing the risk of macrosomia, which is consistent with the results of a previous meta-analysis.[38] This finding is also in line with that described by Juhl et al.[9] who concluded that pregnant women who exercised had a lower risk of having small-for-gestational-age neonates.

Finally, we did not find any differences in the rest of the birth outcomes analyzed. Although a previous study has not found any effect of exercise in the Apgar test,[39] findings regarding the effect on type of birth are still controversial[8,31] and studies exploring the relationship between exercise during pregnancy and umbilical cord blood gas after birth are scarce or non-existent. It is important to note that our exercise training program did not imply any perinatal risk for the mother nor the fetus. Therefore, performing a well-designed exercise program during pregnancy, supervised by physical exercise professionals, is safe and provides health benefits for both the mother and the neonate.

4.1 | Limitations and strengths

This study has limitations that should be highlighted. Firstly, this study may have incurred on selection biases due to the broken randomization component but this is unlikely to have been a determining factor in the quality of the study. Only women interested in joining the study and the final sample size are relatively small. Therefore, the present results should be only extended to pregnant women with similar characteristics, without chronic pathologies and with similar body composition. The loss of some data may have biased this study. Nevertheless, drop-out rates have been similar to other studies in pregnant women,[40] and baseline characteristics were the same in women who dropped out of the study as in those who completed it. However, this study has several strengths that should be noted: (i) the intervention program is a well-designed and professionally supervised exercise program and follows the latest physical activity guidelines in pregnancy, (ii) the intensity and compliance to the exercise program were recorded and only pregnant women who attended at least to 75% of the sessions were included, (iii) all statistical analyses have been adjusted for powerful and objectively measured covariates such as baseline values of muscle strength, cardiorespiratory fitness, and physical activity.

5 | CONCLUSION

The concurrent exercise-training program developed in the GESTAFIT project promoted better maternal and neonatal birth outcomes and did not increase the risk of fetal macrosomia or preterm birth in women with no contraindications to exercise during pregnancy. More research is needed to clarify the mechanisms by which physical exercise increases placental and neonatal birthweights.

6 | PERSPECTIVES

The findings of the present study might be considered relevant for the clinical practice. Previously, our group showed that physical activity improved birth outcomes, especially in relation to umbilical cord blood gas values.[22] The present study shows that a well-designed concurrent physical exercise program is safe for both mother and fetus and promotes better birth outcomes, through a positive effect on labor length and placental weight.

AUTHOR CONTRIBUTIONS

L.B.G. and V.A.A. involved in conceptualization, formal analysis, writing–original draft preparation, and methodology. L.B.G., M.F.A., V.A.A., I.C.-R., O.R.R. and P.A. involved in validation. O.R.R., L.B.G., I.C.R., and M-F-A. involved in investigation. P.A. and V.A.A. involved in resources. V.A.A., L.B.G., M.F.A., I.C.R., P.A. and O.R.R. involved in writing–review and editing. V.A.A. involved on project administration and funding acquisition. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST

None of the authors have any conflict of interests.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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