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Association of physical activity during pregnancy with labor and delivery in nulliparous patients

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ABSTRACT

Background: Physical activity during pregnancy is a positive behavior for improving pregnancy outcomes, yet the relationship between physical activity during pregnancy and labor is still debated.
Objective: This study aimed to test our hypothesis that a higher level of physical activity during pregnancy is associated with a shorter labor duration.
Study design: This was a prospective cohort study of pregnant women with singleton pregnancies and no contraindications to physical activity during pregnancy. physical activity according to type and intensity were evaluated with the Chinese version of the Pregnancy Physical Activity Questionnaire. This questionnaire categorizes physical activities into different types and intensities and quantifies them. The primary study outcome was labor duration. The secondary outcomes were delivery mode, conversion from vaginal delivery to cesarean section, prolonged second stage of labor, perineal tears, episiotomy, and postpartum hemorrhage within 24 hours. Generalized additive models were used to identify both linear and nonlinear relationships between physical activity during pregnancy and labor. A segmented linear model was employed to calculate the saturation effect. Stratified logistic regression was used for subgroup analysis.
Results: In total, 226 women participated in the physical activity survey during pregnancy and gave birth at our hospital. The energy expenditure of physical activity during pregnancy was 145.70 (111.92, 181.69) weekly energy expenditure (MET-h•wk-1). After full adjustment for covariates, a nonlinear relationship was observed between physical activity during pregnancy and the duration of the first stage of labor. Different correlations were observed when the energy expenditure of physical activity during pregnancy was 142.28 MET-h•wk-1. In the two-part regression model, the inflection point of physical activity during pregnancy was at 142.28 MET-h•wk-1. When the energy expenditure of physical activity during pregnancy exceeded 142.28 MET-h•wk-1, each standard deviation increase in physical activity was associated with a decrease of 149.85 minutes in the duration of the first stage of labor (β:-149.85, 95 % CI: −247.54 to −52.17, P = 0.0080).
Conclusions: A nonlinear relationship between physical activity during pregnancy and duration of the first stage of labor ha been identified.When physical activity exceeds 142.28 MET-h•wk-1, each additional standard deviation reduces the first stage of labor by 149.85 minutes. Physical activity is not limited to exercise programs; daily activities such as cleaning, shopping, and walking to and from work are effective ways to increase energy expenditure and help individuals achieve the recommended level of physical activity.

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Introduction

Physical activity during pregnancy can reduce the risk of pregnancy complications and adverse birth outcomes and is recommended as a positive behavior to improve pregnancy outcomes [1–4]. According to the 2020 American College of Obstetricians and Gynecologists (ACOG) guidelines, pregnant women without contraindications should perform 20–30 minutes of moderate-intensity physical activity daily [5]. Current research on the relationship between physical activity during pregnancy and birth outcomes shows varying results. Several studies have suggested that physical activity during pregnancy can reduce the incidence of cesarean delivery and postpartum hemorrhage within 24 hours of delivery, as well as shorten the duration of labor, while other studies have reached opposite conclusions [6,7].

Physical activity is defined as any activity that causes energy expenditure due to skeletal muscle movement, including planned and organized exercise, household chores, occupational activities, and transportation [8].However, most existing studies have focused on specific exercise training programs, such as yoga, birthing ball exercises, and resistance exercises, and their impact on pregnancy outcomes [9–11], overlooking daily physical activities such as household chores, occupational activities, and outings. Although these activities differ from specific exercises such as yoga, they also constitute moderate-intensity activities.

Considering China's large population base, the amount of evidence in relation to pregnant Chinese women relative to pregnant women in Western countries is low, and previous studies have rarely included assessments of daily physical activity. Therefore, this study aimed to evaluate the relationship between physical activity during pregnancy and birth outcomes in Chinese nulliparous patients. Because increased labor involves a higher level of physical activity, the duration of labor was the primary outcome of this study.

Materials and methods

Study design and participants

This was a prospective cohort study. We collected data from nulliparous patients who regularly attended prenatal check-ups at the obstetric outpatient clinic of Shenzhen Second People's Hospital from May to October 2023 and who gave birth in the obstetric ward. The women entered the prospective cohort during their mid-pregnancy (14–27 weeks) prenatal check-ups and signed an informed consent form. Patients were then followed up in late pregnancy (28 +6 weeks to 32 weeks) until delivery. The inclusion criteria were as follows: age$\geq$ 20 years; singleton pregnancy; no previous childbirth experience; no mental or cognitive impairments, capable of effective communication with researchers or able to independently complete questionnaires; voluntary participant in the study and signed informed consent form; healthy prior to pregnancy, and no adverse conditions such as diabetes, hypertension, heart disease, or other physical defects. The exclusion criteria were as follows: adverse complications during pregnancy, such as placenta previa or threatened abortion; serious comorbidities during pregnancy, such as peripartum cardiomyopathy, liver disease, or hematologic disorders; or a history of psychological or psychiatric illnesses [12]. The dropout criteria for participants were as follows: logical errors in the completed questionnaire or incomplete data that affected the analysis of the study results. This study was approved by the ethics review committee of Shenzhen Second People's Hospital (Ethics Approval Number: 2023–015–02PJ).

Exposure

The exposure variable in this study was physical activity in late pregnancy. The physical activity assessment of the study subjects was conducted using the Pregnancy Physical Activity Questionnaire (PPAQ), and physical activity was recorded as a continuous variable. The PPAQ was developed by American scholars, and the Chinese version of the PPAQ was adapted by Chinese scholars in 2012 to suit the local context [13]. This questionnaire has a test-retest reliability of 0.944 and a content validity of 0.940, demonstrating good reliability and validity. This questionnaire is correlated with energy expenditure ($r = 0.768$, $P < 0.001$). The PPAQ distinguishes physical activities by type and intensity, addressing the lack of differentiation among various types of physical activity. The NRS-2002 has been widely used for assessing physical activity levels during pregnancy. The Chinese version of the PPAQ consists of 31 items across four dimensions: 13 items for household activities, 5 for transportation, 8 for recreational exercise, and 5 for occupational activities. Activities are categorized based on intensity, referring to the energy expenditure values outlined in the physical activity guideline, namely, the metabolic equivalent (MET). Each item includes six options, each corresponding to a different weight coefficient. These are then multiplied by the respective energy expenditure values to calculate the weekly energy expenditure of that activity (MET-h•wk-1).

Outcomes

The primary outcome was the duration of labor, defined mainly according to the 'Guidelines for Normal Childbirth' published in 2020 by the Obstetrics and Gynecology Branch of the Chinese Medical Association [14]. Briefly, the definitions of each labor stage are as follows. The first stage, also known as the cervical dilation stage, starts from the onset of labor until the cervix is fully dilated 10 cm. The important signs of labor onset are regular and progressively intensifying uterine contractions, lasting for 30 seconds or more, with intervals of 5–6 minutes, accompanied by progressive disappearance of the cervical canal, dilation of the cervix, and descent of the presenting part. The second stage, also known as the fetal expulsion stage, refers to the entire process from full dilation of the cervix to delivery of the fetus. The third stage, also known as the placental stage, follows the delivery of the fetus and involves the entire process of placental separation and expulsion; this process should take 5–15 minutes and should not exceed 30 minutes.

The secondary outcomes included the mode of delivery, conversion from vaginal delivery to cesarean section (switching to cesarean delivery due to fetal distress or difficulty in head presentation after regular contractions and cervical dilation of more than 3 cm), prolonged second stage of labor (exceeding 3 hours for nulliparous patients without epidural analgesia and 4 hours with epidural analgesia), postpartum hemorrhage within 24 hours, and perineal conditions (episiotomy, perineal tears).

Statistical analysis

Continuous variables are expressed as the mean ± standard deviation (normal distribution) or median (interquartile range) (skewed distribution), and categorical variables are expressed as frequencies or percentages.One-way analysis of variance (ANOVA) (normal distribution), the Kruskal–Wallis H test (skewed distribution), and the chi-square test (categorical variables) were used to determine any significant differences among the groups according to physical activity during pregnancy quartiles. To group the physical activity during pregnancy into quartiles, the physical activity during pregnancy data were ordered from smallest to largest, and the ordered distribution was divided into four parts of equal size. Patients were classified into three groups according to percentile of physical activity during pregnancy, and baseline characteristics were compared among the groups. Univariate analysis with linear regression was performed to evaluate the association between variables and the second stage of labor. The results are expressed as the effect size using regression coefficients and 95 % confidence intervals (CIs). To evaluate the strength of the associations between physical activity during pregnancy and the second stage of labor, we

initially standardized the physical activity during pregnancy data by calculating Z scores. The regression coefficients (for continuous variables) associated with a one standard deviation increase in physical activity during pregnancy were calculated (65.1 MET-h•wk-1). The statistical analysis consisted of three main steps.

Step 1: Univariate and multivariate binary logistic regression models were used. We constructed three distinct models, namely, a unadjusted model (with unadjusted covariates), a minimally adjusted model (with adjustments for sociodemographic variables only), and a fully adjusted model (with adjustments for covariates, as shown in Table 3). Variance infusion factors > 10 were removed from the fully adjusted model. Step 2: Because logistic regression is not suitable for analyses of nonlinear relationships and because there is a possibility of a there being nonlinear relationship between physical activity during pregnancy and the incidence of the second stage of labor, smooth curve fitting (the penalized spline method) was used. The inflection point for physical activity during pregnancy was determined using "exploratory" analyses, which involved moving the trial inflection point along the predefined interval and picking up the point that gave the maximum model likelihood. We also performed a log-likelihood ratio test and compared the one-line linear regression model with a two-piecewise linear model [15,16]. Step 3: To ensure the robustness of the data analysis, we converted PA during pregnancy into a categorical variable based on quartiles for sensitivity analysis to verify the results of PA during pregnancy as a continuous variable.

Analyses were performed using the statistical software package R (http://www.R-project.org, The R Foundation) and EmpowerStats (http://www.empowerstats.com, X&Y Solutions, Inc., Boston, MA, USA). P values < 0.05 (two-sided) were considered to indicate statistical significance.

Results

Baseline characteristics of nulliparous patients

This study included 239 nulliparous women who regularly underwent prenatal check-ups at Shenzhen Second People's Hospital from May to October 2023. Four patients were excluded due to absolute contraindications for physical activity, such as placenta previa; five patients were excluded due to hypertensive disorders of pregnancy; two patients were excluded due to arrhythmia during pregnancy; and 12 patients were excluded due to missing or logically inconsistent data on physical activity during pregnancy. In total, 226 pregnant women completed the survey. 226 pregnant women were divided into three groups based on the level of physical activity - low, medium, and high, with 72 women in each group. The detailed study flowchart is shown in Fig. 1.

The range of physical activity during pregnancy varied from a minimum of 17.50 MET-h•wk-1 to a maximum of 436.32 MET-h•wk-1. The types of physical activity differed among the low-, moderate- and high-level groups. (P < 0.05) (Fig. 2).

The baseline characteristic distributions of the nulliparous women with different levels of physical activity during pregnancy are presented in Table 1. The average age of the nulliparous women was 30.20 ± 3.71 years. The average durations of labor were 584.44 ± 337.91 minutes for the first stage, 71.13 ± 46.80 minutes for the second stage, and 9.35 ± 4.51 minutes for the third stage.

Primary and secondary outcomes in nulliparous patients

A higher level of physical activity during pregnancy was associated with a shorter duration of first-stage labor (591.37 ± 355.85 vs. 678.44 ± 359.21 vs. 471.66 ± 258.93, P = 0.009). The durations of the second and third stages of labor, postpartum hemorrhage within 24 hours, conversion from vaginal delivery to cesarean section, forceps vaginal delivery, prolonged second stage of labor, mode of delivery, perineal tears, and episiotomy were similar across the three groups (Table 2).

Univariate analysis of the first stage of labor

The single-factor analysis indicates an association between oxytocin induction, epidural analgesia, and the first stage of labor (P < 0.05) (Table 3).

Relationship between physical activity and the first stage of labor

Three models were used to assess the relationship between physical activity during pregnancy and the duration of the first stage of labor (Table 4). According to the unadjusted model, no linear relationship was found between physical activity during pregnancy and the duration of the first stage of labor (P = 0.0672). According to Model I, with each increase in the standard deviation of physical activity during pregnancy, there was a decrease of 66.57 minutes in the duration of the first stage of labor (β=-66.57, 95 % CI=-131.02 to −2.12, P = 0.0451). In Model II, a similar association was observed (β: −69.13, 95 % CI: −134.80 to −3.47, P = 0.0413).

For the purpose of sensitivity analysis, physical activity during pregnancy was transformed into a categorical variable based on tertiles,

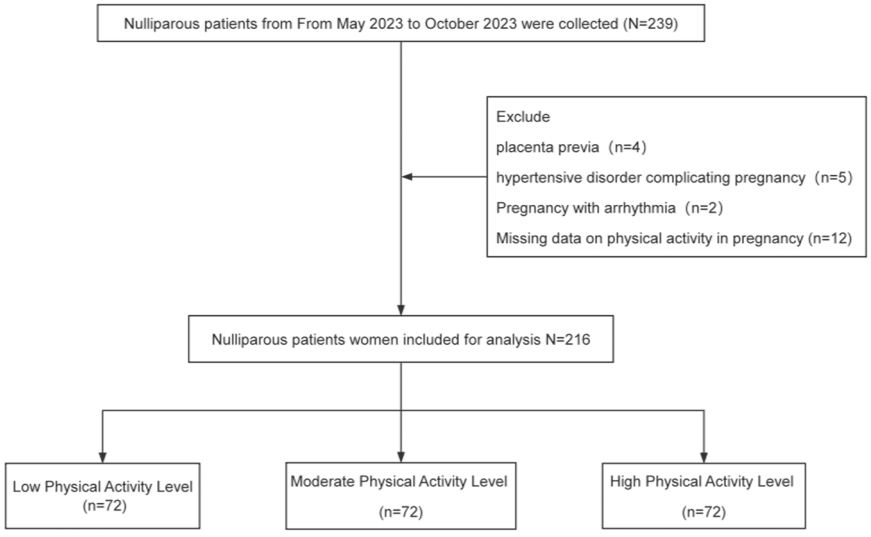

Fig. 1. Description of the study cohort.

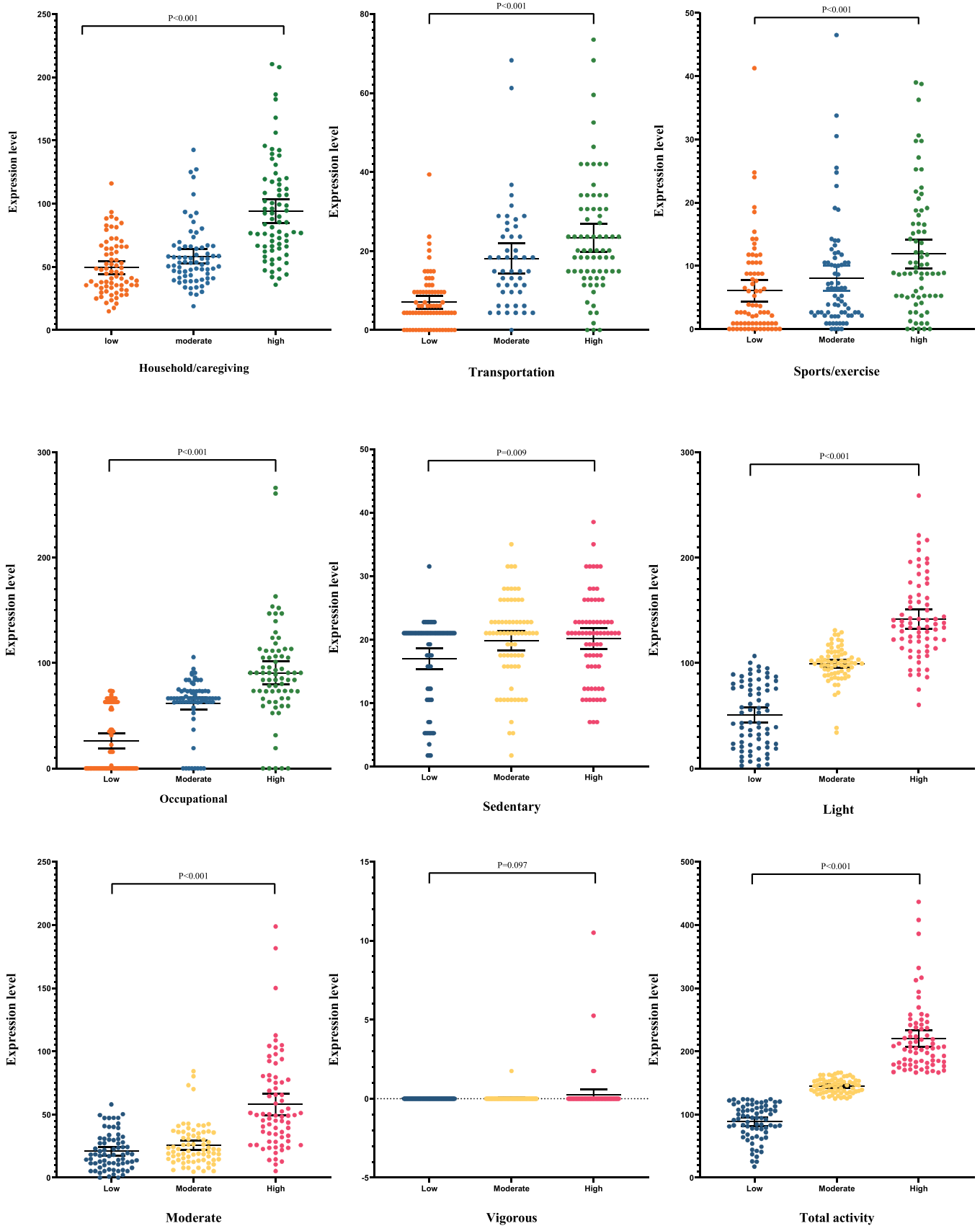

Fig. 2. Breakdown of PPAQ domains by group.

Table 1
Baseline Data of nulliparous patients with different levels of physical activity during pregnancy.

Maternal demographics	Low Physical Activity Level (n = 72)	Moderate Physical Activity Level (n = 72)	High Physical Activity Level (n = 72)	P value
Maternal age, y	30.17 ± 4.24	30.18 ± 3.67	30.25 ± 3.21	0.912
BMI (kg/m^2)	21.09 ± 2.82	20.88 ± 3.12	21.04 ± 2.71	0.604
GA weeks at delivery (wk)	39.19 ± 1.12	38.76 ± 1.14	39.25 ± 0.89	0.010[a]
Weight gain, g	16.47 ± 14.70	11.97 ± 12.21	13.97 ± 8.16	0.293
Labor Fundal Height (cm)	35.74 ± 5.79	33.84 ± 3.27	35.01 ± 1.91	0.004[a]
Labor Abdominal Circumference (cm)	98.25 ± 6.48	97.47 ± 6.09	98.52 ± 5.80	0.497
Birthweight, g	3191.53 ± 394.37	3057.36 ± 318.61	3192.64 ± 441.02	0.149
Advanced maternal age				0.823
No	63 (87.50 %)	65 (90.28 %)	65 (90.28 %)	
Yes	9 (12.50 %)	7 (9.72 %)	7 (9.72 %)	
Educational Level				0.008[a]
High School and Below	14 (19.44 %)	8 (11.11 %)	2 (2.78 %)	
Associate's or Bachelor's Degree	54 (75.00 %)	52 (72.22 %)	61 (84.72 %)	
Graduate Degree and Above	4 (5.56 %)	12 (16.67 %)	9 (12.50 %)	
PROFESSION recoded				< 0.001[a]
Unemployed	22 (30.56 %)	4 (5.56 %)	8 (11.11 %)	
Corporate Employee	47 (65.28 %)	58 (80.56 %)	47 (65.28 %)	
Government Employee	3 (4.17 %)	10 (13.89 %)	17 (23.61 %)	
Average Monthly Household Income Per Capita (Yuan)				0.705
< 10000	23 (31.94 %)	19 (26.39 %)	19 (26.39 %)	
10,000–20,000	26 (36.11 %)	33 (45.83 %)	34 (47.22 %)	
≥ 20,000	23 (31.94 %)	20 (27.78 %)	19 (26.39 %)	
Anticoagulant				0.640
No	66 (91.67 %)	68 (94.44 %)	65 (90.28 %)	
Yes	6 (8.33 %)	4 (5.56 %)	7 (9.72 %)	
pregnancy with Hypothyroidism				0.167
No	63 (87.50 %)	69 (95.83 %)	67 (93.06 %)	
Yes	9 (12.50 %)	3 (4.17 %)	5 (6.94 %)	
Pregnancy Complicated by COVID−19				0.518
No	9 (12.50 %)	8 (11.11 %)	5 (6.94 %)	
Yes	63 (87.50 %)	64 (88.89 %)	67 (93.06 %)	
Pregnancy Intention				0.289
Planned Pregnancy	59 (81.94 %)	54 (75.00 %)	51 (70.83 %)	
Unplanned Pregnancy	13 (18.06 %)	18 (25.00 %)	21 (29.17 %)	
NUMBER.OF. PREGNANCY recoded				0.058
1	49 (68.06 %)	47 (65.28 %)	59 (81.94 %)	
2	11 (15.28 %)	18 (25.00 %)	8 (11.11 %)	
≥ 3	12 (16.67 %)	7 (9.72 %)	5 (6.94 %)	
Oxytocin				0.285
No	17 (41.46 %)	18 (35.29 %)	24 (51.06 %)	
Yes	24 (58.54 %)	33 (64.71 %)	23 (48.94 %)	
Epidural				0.492
No	5 (12.20 %)	11 (21.57 %)	9 (19.15 %)	
Yes	36 (87.80 %)	40 (78.43 %)	38 (80.85 %)	
Newborn Gender				0.154
Male	46 (63.89 %)	36 (50.00 %)	36 (50.00 %)	
Female	26 (36.11 %)	36 (50.00 %)	36 (50.00 %)	
Type of Onset of Labor				0.273
Spontaneous Labor	63 (87.50 %)	56 (77.78 %)	61 (84.72 %)	
Induced Labor	9 (12.50 %)	16 (22.22 %)	11 (15.28 %)	
Anemia				0.829
No	26 (36.11 %)	31 (43.06 %)	25(34.72 %)	
Mild	21 (29.17 %)	21 (29.17 %)	23 (31.94 %)	
Moderate	25 (34.72 %)	20 (27.78 %)	24 (33.33 %)	

Data represent number (percentage) or (standard deviation).
GA, gestation age.
[a] Clinically significant.

and the P value for trend tests was calculated. The results indicated a consistent increasing trend in both Model I and Model II (all $P < 0.05$).

Results of the nonlinear relationship between physical activity during pregnancy and the first stage of labor

Our findings revealed a nonlinear relationship on the association between physical activity during pregnancy and the duration of the first stage of labor after we adjusted for age, educational level, occupation, household monthly income per capita, number of pregnancies, pre-pregnancy BMI, and anemia. The inflection point was determined to be at 142.28 MET-h•wk-1.When physical activity during pregnancy exceeded 142.28 MET-h•wk-1, each increase in physical activity was associated with a 149.85-minute reduction in the duration of the first stage of labor (β: −149.85, 95 % CI: −247.54 to −52.17; P = 0.0080). However, when physical activity during pregnancy was less than 142.28 MET-h•wk-1, there was no significant association between the first stage of labor and physical activity during pregnancy (β: 103.91, 95 % CI: −38.93–246.75, P = 0.1565) (see Fig. 3 and Table 5).

Sensitivity analysis

To ensure the reliability of our study findings, we conducted sensitivity analyses. After controlling for prepregnancy body mass index (BMI) within the normal range (18.5–24 kg/m2), we found that the association between physical activity during pregnancy and the duration of the first stage of labor may not have reached statistical significance due to the small sample size, but the segmentation effect persisted (Table 6). In another model, where we restricted the sample to women who did not experience anemia, similar trends were observed (Table 7).

Table 2
Primary and secondary outcomes in nulliparous patients.

Outcome	Low Physical Activity Level (n = 72)	Moderate Physical Activity Level (n = 72)	High Physical Activity Level (n = 72)	P value
Duration of first stage, min	591.37 ± 355.85	678.44 ± 359.21	471.66 ± 258.93	0.009[a]
Duration of second stage, min	79.77 ± 44.81	60.81 ± 46.02	71.94 ± 43.95	0.130
Duration of third stage, min	8.90 ± 4.10	9.39 ± 4.05	9.32 ± 4.14	0.831
PPH	413.47 ± 134.72	413.99 ± 185.78	404.24 ± 142.79	0.915
Conversion from Vaginal Delivery to Cesarean Section				0.345
No	66 (91.67 %)	70 (97.22 %)	67 (93.06 %)	
Yes	6 (8.33 %)	2 (2.78 %)	5 (6.94 %)	
Forceps Vaginal Delivery				0.591
No	42 (97.67 %)	51 (98.08 %)	48 (100.00 %)	
Yes	1 (2.33 %)	1 (1.92 %)	0 (0.00 %)	
Prolonged second stage				0.419
No	41 (100.00 %)	50 (98.04 %)	47 (100.00 %)	
Yes	0 (0.00 %)	1 (1.96 %)	0 (0.00 %)	
Delivery way				0.216
Vaginal delivery	42 (58.33 %)	52 (72.22 %)	47 (65.28 %)	
Cesarean delivery	30 (41.67 %)	20 (27.78 %)	25 (34.72 %)	
Perineum				0.086
Episiotomy	19 (46.34 %)	15 (29.41 %)	24 (50.00 %)	
First Degree Perineal Tear	22 (53.66 %)	36 (70.59 %)	24 (50.00 %)	

Data represent number (percentage) or (standard deviation).
PPH , Postpartum Hemorrhage within 24 Hours
[a] Clinically significant.

This suggests that while statistical significance may be limited by the size of the sample, the effects we observed are consistent across different subgroups, thereby reinforcing the robustness of our study results.

In Table 6, a sensitivity analysis with prepregnancy BMI controlled within the normal range of 18.5–24 kg/m2. This control aimed to assess the relationship between physical activity and pregnancy outcomes in pregnant women within the standard weight range, providing more targeted insights, particularly regarding the potential impact of weight on these relationships.

In Table 7, a sensitivity analysis was conducted on pregnant women who were not anemic. Such analysis helps us to more deeply understand the potential impact of anemic conditions on the study results, especially when considering the influence of health status during pregnancy on pregnancy outcomes. By analyzing non-anemic pregnant women, we can more accurately assess the impact of other factors such as physical activity on pregnancy outcomes.

Comment

Principal findings

In this study, we aimed to identify the impact of physical activity during pregnancy on birth outcomes. Our main findings were as follow: (1) A U-shaped association was found between physical activity during pregnancy and the duration of the first stage of labor. These associations showed differing correlations at the inflection point, specifically when the energy expenditure of physical activity during pregnancy was 142.28 MET-h•wk-1. When the energy expenditure of physical activity

Table 3
Univariate Analysis of the First Stage of Labor.

	Statistics	OR(95 %CI)	p value
Age	29.40 ± 2.94	2.51 (−16.82 , 21.85)	0.7992
BMI prepregnancy BMI	20.89 ± 2.92	2.29 (−17.05 , 21.62)	0.8170
Weight Before Delivery (kg)	65.40 ± 9.16	−2.07 (−8.19 , 4.05)	0.5090
Weight Gain During Pregnancy (kg)	12.92 ± 10.52	−2.37 (−7.69 , 2.94)	0.3829
Educational Level			
High School or Below	15 (10.64 %)	1.0	
College or Bachelor's Degree	109 (77.30 %)	−86.21 (−267.90 , 95.48)	0.3540
Graduate Degree or Above	17 (12.06 %)	−187.35 (−420.79 , 46.10 %)	0.1181
Occupation			
Unemployed	22 (15.60 %)	1.0	
Corporate Employee	98 (69.50 %)	−35.19 (−192.27 , 121.89)	0.6613
Public Servant	21 (14.89 %)	−35.72 (−233.47 , 167.02)	0.7304
Average Monthly Household Income (Yuan)			
< 10,000	40 (28.37 %)	1.0	
10,000–20,000	62 (43.97 %)	−12.25 (−149.05 , 124.55)	0.8609
≥ 20,000	39 (27.66 %)	−47.92 (−199.27 , 103.43)	0.5359
COVID−19			
No	15 (10.64 %)	1.0	
Yes	126 (89.36 %)	−2.95 (−184.09 , 178.19)	0.9745
Pregnancy Intention			
Planned Pregnancy	106 (75.18 %)	1.0	
Unplanned Pregnancy	35 (24.82 %)	26.04 (−103.37 , 155.45)	0.6939
Method of Conception			
Natural Conception	103 (74.10 %)	1.0	
Assisted Reproduction	36 (25.90 %)	14.60 (−113.67 , 142.87)	0.8238
Anemia During Pregnancy			
None	52 (36.88 %)	1.0	
Mild Anemia	44 (31.21 %)	99.68 (−35.30 , 234.67)	0.1501
Moderate to Severe Anemia	45 (31.91 %)	125.02 (−9.96 , 260.00)	0.0717
Premature Rupture of Membranes			
No	114 (80.85 %)	1.0	
Yes	27 (24.82 %)	26.04 (−103.37 , 155.45)	0.6939
Number of Pregnancies			
1	113 (80.14 %)	1.0	
2	20 (14.18 %)	−35.83 (−197.13 , 125.47)	0.6640
≥ 3	8 (5.67 %)	−65.73 (−308.80 , 177.35)	0.5970
Cervical Maturity at Admission (Bishop Score)			
Amount of Oxytocin Used	1.91 ± 2.30	45.93 (22.68 , 69.18)	0.0002
Pain Relief During Labor			
No	25 (17.99 %)	1.0	

(*continued on next page*)

Table 3 (*continued*)

	Statistics	OR(95 %CI)	p value
Yes	114 (82.01 %)	282.27 (143.78 , 420.76)	0.0001
Onset of Labor			
Spontaneous	103 (74.10 %)	1.0	
Medically Induced	36 (25.90 %)	14.60 (−113.67 , 142.87)	0.8238
Gestational Week at Delivery	39.20 ± 1.13	14.01 (−35.67 , 63.69)	0.5813
Newborn gender			
Male	74 (52.48 %)	1.0	
Female	67 (47.52 %)	−33.41 (−145.75 , 78.93)	0.5609
Newborn weight (g)	3113.23 ± 369.28	0.07 (−0.08 , 0.22)	0.3538
Newborn head circumference (cm)	32.98 ± 1.16	21.67 (−26.91 , 70.25)	0.3835
Neonatal length (cm)	48.73 ± 4.25	−1.13 (−14.34 , 12.08)	0.8675
NICU			
No	95 (67.38 %)	1.0	
Yes	46 (32.62 %)	67.90 (−51.68 , 187.47)	0.2677
Postpartum Hemorrhage Within 24 Hours (ml)	366.72 ± 105.14	0.02 (−0.51 , 0.56)	0.9340

Table 4
Relationship between physical activity during pregnancy and the duration of the first stage of labor.

Exposure	Unadjusted p value	Adjustment I p value	Adjustment II p value
Physical Activity During Pregnancy	−0.815 (−1.680, 0.0051) 0.0672	−1.03 (−2.02.−0.03) 0.0451	−1.07 (−2.08, −0.05) 0.0413
Physical Activity During Pregnancy per-SD change	−52.89 (−109.07, 3.29) 0.0672	−66.57 (−131.02, −2.12) 0.0451	−69.13 (−134.80, −3.47) 0.0413
group			
Low Physical Activity Level	1.0	1.0	1.0
Moderate Physical Activity Level	87.07 (−47.64, 221.78) 0.2074	88.90 (−60.06, 237.87) 0.2444	124.80 (−23.43, 273.03) 0.1016
High Physical Activity Level	−119.70 (−256.94, 17.54) 0.0896	−139.87 (−290.89, 11.15) 0.0719	−142.86 (−295.96, 10.24) 0.0700
P for trend	0.0672	0.0451	0.0413

Unadjusted M (unadjusted model): No adjustment.
Adjusted MI (adjusted Model I): adjusted for age, education, profession, and per capita monthly household income.
Adjusted MII (adjusted model II): adjusted for age, education level, occupation, average monthly family income, number of pregnancies, anemia, and BMI (kg/m^2).

during pregnancy exceeded 142.28 MET-h•wk-1, each standard deviation increase in physical activity led to a reduction in the duration of the first stage of labor of 149.85 minutes. (2) Physical activity during pregnancy is not only limited to exercise programs but also includes daily activities such as household chores, outings, and occupational activities, which significantly impact birth outcomes during pregnancy. (3) The durations of the second and third stages of labor, postpartum hemorrhage within 24 hours, conversion from vaginal delivery to cesarean section, forceps vaginal delivery, prolonged second stage of labor, mode of delivery, perineal tear, and episiotomy were similar across the three groups.

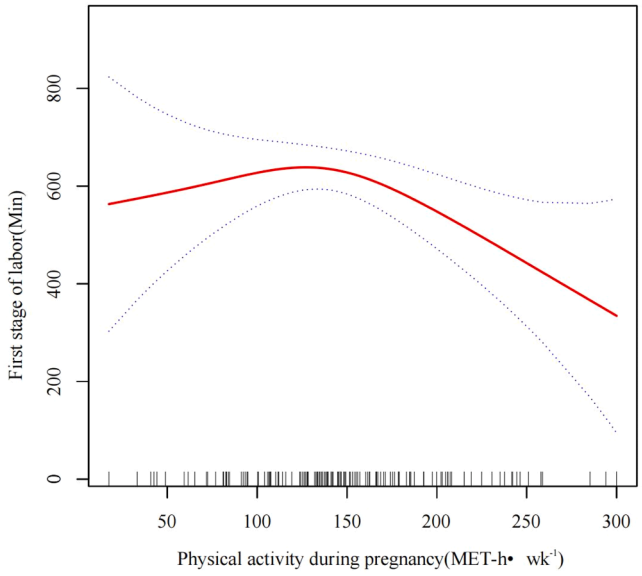

Fig. 3. Relationships between physical activity during pregnancy and childbirth. Association between physical activity during pregnancy and first of labor. A nonlinear association between physical activity during pregnancy and first stage of labor was found via a generalized additive model (GAM). The solid red line represents the smooth curve fit between variables. The blue bands represent the 95 % confidence intervals (CIs) from the fits. All the data were adjusted for age, educational level, occupation, average monthly family income, number of pregnancies, and anemia.

Table 5
Analysis of the threshold effect of physical activity during pregnancy on the first stage of labor.

	The first stage of labor (MET-h•wk^{-1})	The first stage of labor (Z score)
Model I		
Linear effect	−0.99 (−2.15, 0.17) 0.0970	−58.38 (−126.81, 10.04) 0.0970
Model II		
Inflection point	142.28	−0.12
< 144.8	1.76 (−0.66, 4.18) 0.1565	103.91 (−38.93, 246.75) 0.1565
≥ 144.8	−2.54 (−4.19, −0.88) 0.0032	−149.85 (−247.54, −52.17) 0.0032
P for log likely ratio test	0.0080	0.0080

Effect: the First Stage of Labor, Cause: Physical Activity during Pregnancy
Adjusted for age, educational level, occupation, average monthly family income, number of pregnancies, and anemia.

Results of the study in the context of other observations

Current research on the relationship between physical activity during pregnancy and birth outcomes is controversial. Findings from the study by Veisy A et al. indicate that physical activity during pregnancy does not affect the duration of labor [17]. Research by Masoud and colleagues revealed that physical activity during pregnancy significantly reduces the duration of the second stage of labor, but no difference is observed in the first stage [18]. The results of a randomized controlled trial involving aerobic and resistance exercises in 159 pregnant showed that, compared to the women in the nonexercising group, those in the exercising group had an 80.8-minute longer first stage of labor and a 29.8-minute shorter second stage of labor [19]. However, our study demonstrated a U-shaped association between physical activity during pregnancy and the duration of the first stage of labor. We think that the differences in these findings can be attributed to the following: (1) our

Table 6
Sensitivity analysis.

Exposure	Unadjusted p value	Adjustment I p value	Adjustment II p value
Physical Activity During Pregnancy	−0.88 (−1.90, 0.15) 0.0972	−0.67 (−2.00, 0.66) 0.3285	−0.78 (−2.18, 0.61) 0.2746
Physical Activity During Pregnancy per-SD change group	−56.81 (−123.24, 9.63) 0.0972	−43.36 (−129.78, 43.06) 0.3285	−50.80 (−141.23, 39.64) 0.2746
Low Physical Activity Level	1.0	1.0	1.0
Moderate Physical Activity Level	142.07 (−13.45, 297.59) 0.0767	184.99 (17.44, 352.54) 0.0336	185.83 (18.81,352.86) 0.0325
High Physical Activity Level	77.82 (−227.88, 72.25) 0.3122	−29.92 (−196.69, 136.88) 0.7262	−57.90 (−230.63, 114.83) 0.5133
P for trends	0.0972	0.3285	0.2746

Table 7
Sensitivity analysis.

Exposure	Unadjusted p value	Adjustment I p value	Adjustment II p value
Physical Activity During Pregnancy	−1.05 (−2.82, 0.72) 0.2523	−0.76 (−2.96, 1.44) 0.5028	−0.80 (−3.13, 1.54) 0.5091
Physical Activity During Pregnancy per-SD change group	−67.91 (−182.82, 46.99) 0.2523	−49.32 (−192.15, 93.51) 0.5028	−51.61 (−203.22, 100.00) 0.5091
Low Physical Activity Level	1.0	1.0	1.0
Moderate Physical Activity Level	67.22 (−153.85, 288.29) 0.5540	45.26 (−237.22, 327.74) 0.7554	44.45 (−255.03, 343.92) 0.7730
High Physical Activity Level	−233.19 (−453.99, 7.61) 0.0641	−208.84 (−484.65, 66.97) 0.1467	−224.90 (−521.78, 71.98) 0.1471
P for trends	0.0495	0.1116	0.1094

study population was Chinese; (2) unlike that of Veisy A's study, our research design was a prospective cohort study; (3) our assessment of physical activity was broader in that it included all possible types of physical activity among pregnant women, such as household care, occupational activities, and outings, in contrast to the specific forms of exercise, such as yoga or Pilates, considered in the aforementioned studies; and (4) different methodologies, such as generalized additive models (GAMs), were used in our study to explore the relationship between physical activity during pregnancy and the duration of labor, and the correlation was determined through smooth curve fitting.

A previous meta-analysis incorporating 60 randomized controlled trials showed that physical activity during pregnancy can reduce the duration of the first stage of labor by 62.26 minutes, with no association found between physical activity during pregnancy and the duration of the second or third stage of labor [20]. A randomized controlled trial by Rodriguez et al., which included 120 healthy pregnant women, demonstrated that the exercising group had a 145-minute shorter first stage of labor than the nonexercising group [21]. Similarly, our study in the adjusted model showed that for each standard deviation increase in physical activity during pregnancy, there was an average reduction of 149.85 minutes in the duration of the first stage of labor (β: −149.85, 95 % CI: −247.54 to −52.17, P = 0.0080). Therefore, our study corroborates the association between physical activity during pregnancy and the duration of the first stage of labor.

Although current studies do not fully explain the underlying reasons, the following aspects may be relevant. First, this study included only primiparas who may experience a fear of childbirth and antenatal anxiety for various reasons, such as a lack of knowledge about childbirth. These negative emotions can place expectant mothers in a high state of alertness [22,23], leading to sympathetic nervous system arousal and increased levels of catecholamines, adrenocortical hormones, and cortisol, which cause pain syndrome. This disrupts the coordination between uterine contractions and cervical dilation, resulting in prolonged or stalled labor. However, physical activity during pregnancy can alleviate these adverse emotions by increasing brain serotonin levels, reducing hypothalamic—pituitary—adrenal (HPA) axis activity, and promoting the release of natural painkillers and endorphins. This helps expectant mothers relax, potentially shortening the duration of labor [24–27].Second, physical activity during pregnancy enhances the maximum oxygen uptake of nulliparous patients and strengthens cardiopulmonary function and vascular elasticity, providing support for nulliparous patients to better handle the physical demands of childbirth [28–30]. Additionally, physical activity during pregnancy promotes placental growth and functional enhancement, ensuring adequate oxygen supply for the fetus during the progression of labor and maintaining acid–base balance, thereby reducing the occurrence of fetal distress [31,32]. Finally, physical activity can stimulate the release of norepinephrine, effectively enhancing uterine contractility. Additionally, physical activity plays a central role in the physiological mechanism of skeletal muscles, particularly in the process of forming cross-bridges between actin and myosin [33]. This process leads to the release of calcium ions and triggers the excitation-contraction coupling phenomenon, which is the fundamental mechanism of muscle contraction [34]. Notably, this calcium activation is not limited to skeletal muscles; it may also be closely associated with the contraction of smooth muscles. Particularly in the physiological process of uterine contractions, the activation of calcium channels may play a significant role [35,36]. Therefore, engaging in physical activity not only enhances the function and health of overall muscles but also promotes uterine contractions.

In this study, using a two-piecewise linear model and a recursive algorithm, the inflection point was determined to be at 142.28 MET-h•wk-1. After the patients were divided into two groups based on this inflection point, significant differences were observed between the groups in terms of educational level and occupational distribution (see Supplementary Table SI). Specifically, compared to those in the group with less than 142.28 MET-h•wk-1, the proportions of individuals with an associate's or bachelor's degree increased from 71.43 % to 82.88 % in the group with more than 142.28 MET-h•wk-1. Additionally, the proportion of individuals with a graduate degree or higher also increased, from 9.52 % to 13.51 %. This finding may reflect a positive correlation between higher educational levels and certain key variables (e.g., income, health knowledge, health behaviors), which may be associated with health outcomes related to the 142.28 MET-h•wk-1 benchmark. In terms of occupational distribution, we observed a significant increase in the proportion of government employees in the group exceeding MET-h•wk-1, from 5.71 % to 21.62 %. This may indicate a higher likelihood of greater physical activity levels during pregnancy among government employees, possibly related to the generally higher stability and benefits associated with government positions.

Strengths and limitations

The main strengths of this study are as follows. First, the assessment of physical activity during pregnancy not only encompasses the daily physical activities of nulliparous women but also is not limited to any specific type of exercise, which enhances the generalizability and real-world applicability of the findings. Second, this study employed sensitivity analysis and algorithmic models to assess the nonlinear relationship between physical activity and the duration of the first stage of labor. Unlike most previous studies that focused solely on the intensity or duration of physical activity, this study quantified weekly energy expenditure, which allowed for a more detailed exploration of the complex relationship between physical activity dosage and labor progression. An important inflection point was identified, offering new insights into the association between physical activity levels during

pregnancy and the labor process. Additionally, the study adjusted for multiple potential confounders, strengthening the robustness and reliability of the results and further ensuring the generalizability and scientific validity of the conclusions.

This study also has several limitations. First, only healthy pregnant women were included. Future studies should focus on whether there is a relationship between physical activity and the duration of labor in pregnant women with pregnancy complications or comorbidities. As an observational study, this study is inevitably subject to confounding factors, but we addressed this by incorporating strict adjustments for confounders and assessed the robustness of our results through sensitivity analysis. We were able to adjust for measurable confounders but not unmeasurable confounders, such as genetics and environment. Therefore, it is necessary to conduct higher-level clinical studies in more populations to validate our findings. Additionally, the relatively small sample size may not have been sufficient to explore the effects of physical activity on secondary outcomes, such as the duration of the second and third stages of labor, postpartum hemorrhage, and other delivery-related factors. However, this limitation does not impact the validity of our core findings regarding the relationship between physical activity during pregnancy and the duration of the first stage of labor. Future studies with larger and more diverse populations are needed to validate and expand on these findings.

Conclusion

In summary, our foundings show that a high level of physical activity during pregnancy, with energy expenditure of physical activity reaches 142.28 MET-h•wk-1, are association with a shorted duration of the first stage of labor. This finding highlights the importance of everyday activities, such as household chores, outings, and occupational activities, as effective ways to increase energy expenditure and meet the activity levels recommended by the ACOG guidelines.

For clinicians, this suggests that encouraging pregnant women to incorporate daily physical activities into their routines—rather than solely relying on structured exercise programs—could be a practical and accessible approach to promote labor progression and improve maternal well-being. For pregnant women, these activities not only help maintain physical vitality but also reduce pregnancy-related stress and improve overall quality of life.

Given the impact of physical activity on labor outcomes, healthcare providers should consider advising expectant mothers on how to integrate daily movements into their lifestyle, especially for those who may find it difficult to engage in formal exercise. Further research is needed to explore the quantitative relationship between different types and intensities of physical activity and birth outcomes, particularly in women with pregnancy complications and comorbidities.

Ethics statement

This study has obtained approval from the Ethics Committee of the Second People's Hospital of Shenzhen (Approval No: 202301502PJ) and the protocol was registered with ClinicalTrials.gov (registration number: ChiCTR2300078381). This study was conducted in accordance with the principles of the Declaration of Helsinki. The participants provided their written informed consent to participate in this study.

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CRediT authorship contribution statement

Xiaohong You: Writing – review & editing. **Liyin Luo:** Writing – review & editing, Investigation. **Qian Zhao:** Writing – review & editing, Formal analysis. **Aihong Jin:** Writing – review & editing, Writing – original draft, Supervision, Methodology. **Shuqun Ren:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this article'.

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Data availability statement

The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

References

[1] Barakat R, Pelaez M, Cordero Y, et al. Exercise during pregnancy protects against hypertension and macrosomia: randomized clinical trial[J]. Am J Obstet Gynecol 2016;214(5):641–9.
[2] Weng YM, Green J, Yu JJ, et al. The relationship between incidence of cesarean section and physical activity during pregnancy among pregnant women of diverse age groups: Dose-response meta-analysis[J]. Int J Gynaecol Obstet 2023.
[3] Davenport MH, Ruchat SM, Poitras VJ, et al. Prenatal exercise for the prevention of gestational diabetes mellitus and hypertensive disorders of pregnancy: a systematic review and meta-analysis[J]. Br J Sports Med 2018;52(21):1367–75.
[4] Ribeiro MM, Andrade A, Nunes I. Physical exercise in pregnancy: benefits, risks and prescription[J]. J Perinat Med 2022;50(1):4–17.
[5] Physical Activity and Exercise During Pregnancy and the Postpartum Period: ACOG Committee Opinion, Number 804[J]. Obstet Gynecol. 2020, 135(4): e178-e188..
[6] Ferreira C, Guerra C, Silva A, et al. Exercise in pregnancy: the impact of an intervention program in the duration of labor and mode of delivery[J]. Rev Bras Ginecol Obstet 2019;41(2):68–75.
[7] Watkins VY, O'Donnell CM, Perez M, et al. The impact of physical activity during pregnancy on labor and delivery[J]. Am J Obstet Gynecol 2021;225(4):431–7.
[8] Bull FC, Al-Ansari SS, Biddle S, et al. World Health Organization 2020 guidelines on physical activity and sedentary behaviour[J]. Br J Sports Med 2020;54(24):1451–62.
[9] Wadhwa Y, Alghadir AH, Iqbal ZA. Effect of antenatal exercises, including yoga, on the course of labor, delivery and pregnancy: a retrospective study[J]. Int J Environ Res Public Health 2020;17(15).
[10] Fournier D, Feeney G, Mathieu ME. Outcomes of exercise training following the use of a birthing ball during pregnancy and delivery[J]. J Strength Cond Res 2017;31(7):1941–7.
[11] Bolanthakodi C, Raghunandan C, Saili A, et al. Prenatal Yoga: effects on alleviation of labor pain and birth outcomes[J]. J Alter Complement Med 2018;24(12):1181–8.
[12] Mottola MF, Davenport MH, Ruchat SM, et al. 2019 Canadian guideline for physical activity throughout pregnancy[J]. Br J Sports Med 2018;52(21):1339–46.
[13] 张燕，赵岳，董胜雯，等. 中文版孕期身体活动问卷信效度评定[J]. 中华护理杂志. 2013, 48(09): 825–827..
[14] 何镭，刘兴会. 正常分娩指南(2020)要点解读——产程的观察及处理[J]. Shi yong fu chan ke za zhi. 2021, 37(2): 95–96..
[15] Liu EH, Liao WZ, Chen HK, Huang XY, Li RX, Liang HW, Guo XG. Association between serum vitamin E and bacterial vaginitis in women: a cross-sectional study. BMC Women's Health 2024;24(1):316.
[16] Li W, Song J, Chen Z. The association between dietary vitamin C intake and periodontitis: result from the NHANES (2009-2014). BMC Oral Health 2022;22(1):390.
[17] Veisy A, Mohammad ACS, Hematzadeh S, et al. Effect of prenatal aerobic exercises on maternal and neonatal outcomes: A systematic review and meta-analysis[J]. Nurs Open 2021;8(5):2301–17.

[18] Masoud AT, Abdelgawad MM, Elshamy NH, et al. The effect of antenatal exercise on delivery outcomes: A systematic review and meta-analysis of randomized controlled trials[J]. J Gynecol Obstet Hum Reprod 2020;49(6):101736.
[19] Baena-Garcia L, de la Flor-Alemany M, Coll-Risco I, et al. A concurrent prenatal exercise program increases neonatal and placental weight and shortens labor: The GESTAFIT project[J]. Scand J Med Sci Sports 2023;33(4):465–74.
[20] Zhang D, Ruchat SM, Silva-Jose C, et al. Influence of physical activity during pregnancy on type and duration of delivery, and epidural use: systematic review and meta-analysis[J]. J Clin Med 2023;12(15).
[21] Rodriguez-Blanque R, Sanchez-Garcia JC, Sanchez-Lopez AM, et al. Physical activity during pregnancy and its influence on delivery time: a randomized clinical trial[J]. PeerJ 2019;7:e6370.
[22] Dencker A, Nilsson C, Begley C, et al. Causes and outcomes in studies of fear of childbirth: A systematic review[J]. Women Birth 2019;32(2):99–111.
[23] Pettersson FD, Hellgren C, Nyberg F, et al. Depressed mood, anxiety, and the use of labor analgesia[J]. Arch Women's Ment Health 2016;19(1):11–6.
[24] Naghibi S, Barzegari A, Shariatzadeh M, et al. Voluntary physical activity increases maternal care and reduces anxiety- and depression-related behaviours during the postpartum period in mice[J]. Brain Res 2022;1784:147880.
[25] Gobinath AR, Wong S, Chow C, et al. Maternal exercise increases but concurrent maternal fluoxetine prevents the increase in hippocampal neurogenesis of adult offspring[J]. Psychoneuroendocrinology 2018;91:186–97.
[26] Dabo F, Nyberg F, Qin Z, et al. Plasma levels of beta-endorphin during pregnancy and use of labor analgesia[J]. Reprod Sci 2010;17(8):742–7.
[27] Yuksel O, Ates M, Kizildag S, et al. Regular aerobic voluntary exercise increased oxytocin in female mice: the cause of decreased anxiety and increased empathy-like behaviors[J. Balk Med J 2019;36(5):257–62.
[28] Altinayak SO, Ozkan H. The effects of conventional, warm and cold acupressure on the pain perceptions and beta-endorphin plasma levels of primiparous women in labor: A randomized controlled trial[J]. Explor (NY) 2022;18(5):545–50.
[29] Perales M, Santos-Lozano A, Ruiz JR, et al. Benefits of aerobic or resistance training during pregnancy on maternal health and perinatal outcomes: A systematic review [J]. Early Hum Dev 2016;94:43–8.
[30] Seneviratne SN, Jiang Y, Derraik J, et al. Effects of antenatal exercise in overweight and obese pregnant women on maternal and perinatal outcomes: a randomised controlled trial[J]. BJOG 2016;123(4):588–97.
[31] Bhattacharjee J, Mohammad S, Goudreau AD, et al. Physical activity differentially regulates VEGF, PlGF, and their receptors in the human placenta[J]. Physiol Rep 2021;9(2):e14710.
[32] Bhattacharjee J, Mohammad S, Adamo KB. Does exercise during pregnancy impact organs or structures of the maternal-fetal interface?[J]. Tissue Cell 2021;72: 101543.
[33] Suhr F, Gehlert S, Grau M, et al. Skeletal muscle function during exercise-fine-tuning of diverse subsystems by nitric oxide[J]. Int J Mol Sci 2013;14(4):7109–39.
[34] Jurek B, Neumann ID. The oxytocin receptor: from intracellular signaling to behavior[J]. Physiol Rev 2018;98(3):1805–908.
[35] Wray S, Jones K, Kupittayanant S, et al. Calcium signaling and uterine contractility [J]. J Soc Gynecol Invest 2003;10(5):252–64.
[36] Bernstein K, Vink JY, Fu XW, et al. Calcium-activated chloride channels anoctamin 1 and 2 promote murine uterine smooth muscle contractility[J]. Am J Obstet Gynecol 2014;211(6):681–8.