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The association between objectively-measured physical activity during pregnancy and the risk of cesarean delivery: a prospective study

Short title: Physical activity and cesarean delivery

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ABSTRACT

Objectives: To evaluate the association between physical activity (PA) and risk of cesarean delivery.

Material and methods: 197 singleton pregnant women recruited in this study. Participants were divided into vaginal and cesarean delivery group. PA based objectively monitoring between the two groups was compared. Logistic regression was used to analyze the association between PA and cesarean delivery.

Results: Moderate PA (MPA) of cesarean delivery group was less in the first (21.5 vs 27.5 min/day; p = 0.006) and second trimester (19.4 vs 26.8 min/day; p = 0.001). Light PA of cesarean delivery group was less (195.9 vs 217.3 min/day; p = 0.006)

with more sedentary time (551.7 vs 529.1 min/day; p = 0.041) in the third trimester. Increased risk of cesarean delivery was noted in cases with MPA < 37.8 min/day compared to MPA ≥ 37.8 min/day (aOR 2.62; 95% CI 1.09 to 6.32; p = 0.031) in the first trimester. MPA < 17.9 min/day in the second trimester increased the risk of cesarean delivery (aOR 3.01; 95% CI 1.57 to 5.75; p = 0.001) compared to MPA ≥ 17.9 min/day.

Conclusions: MPA in the first two trimesters were associated with the risk of cesarean section. Women should increase MPA from early pregnancy.

Key words: delivery; physical activity; pregnancy; risk

INTRODUCTION

Cesarean delivery increased the risk of placenta previa and placenta accreta in second pregnancy, and affected the long-term prognosis of both mother and child [1]. The rate of cesarean delivery has increased from 28.8% in 2008 to 34.9% in 2014 in China [2]. With the implementation of the two-child policy, the multipara and elderly and high-risk women as well as the rate of cesarean delivery had increased [3]. Therefore, interventions aim to reduce the rate of cesarean delivery, especially in primipara¸ should be explored.

Physical activity (PA) is one of the modifiable factors that may improve pregnancy outcomes. PA during pregnancy has beneficial on mother and fetus[4]. But the influence of PA on the risk of cesarean delivery was controversial. A meta-analysis showed that PA during pregnancy and nutritional intervention could reduce the risk of cesarean section [5]. However, research from Karabulut et al. showed that moderate PA during pregnancy has no effect on delivery methods [6]. In addition, few studies have compared the PA differences between vaginal delivery and cesarean delivery during pregnancy.

Few studies explored the effect of objectively PA on the mode of delivery. Therefore, we aim to analyze the difference of objectively measured PA between vaginal delivery and cesarean delivery and explore the relationship between PA and cesarean delivery.

MATERIAL AND METHODS

This data were secondary analysis from a prospective study. Singleton pregnant women at 10–14 weeks of gestation with no contraindications were recruited in the First Affiliated Hospital of Sun Yat-Sen University from March 2018 to March 2020. The inclusion criteria included first-time participation at 10–14 weeks; age 18 to 40 years; single live fetus without malformation; primipara or the second child pregnant women, and no hypertension, diabetes, or heart disease. The exclusion criteria included twin or multiple pregnancies; the third or more child pregnancy; cervical insufficiency; threatened abortion; placenta previa; chronic diseases such as chronic kidney disease, mental disorders; and refusal to participate in the study. Participants were divided into vaginal delivery group or cesarean delivery group based on delivery outcome. This study was approved by the Ethics Committee of the First Affiliated Hospital, Sun Yat-Sen University (2017–296) and followed the tenets of the Declaration of Helsinki and the Good Clinical Practice. All participants had signed informed consent before participating in the study.

The sample size was calculated according to a small-to-moderate correlation (approximately 0.20) with an 80% statistical power and using two-tailed probability level of 5%. The sample size was 213 considering 10% potential lost rate in follow-up.

Data collection

Demographic data including maternal age, parity, way of conception, marital status, history of cesarean section, education level (high school and below, university and above), work status (full-time job, other), annual family income (annually income < 10000 CNY/person as low income, ≥ 10000 CNY/person as high income), weight before pregnancy (kg), height (cm), and smoking status were collected at the first visit. Delivery data including gestation age, mode of delivery (vaginal delivery or cesarean delivery) and birth weight (kg) were collected via the electronic medical

record system. And pre-pregnancy body mass index (pre-pregnancy BMI, unit: kg/m^2) was calculated.

PA measurement

A triaxial accelerometer (Actigraph GT3X plus, Actigraph Inc., Florida, USA) was used for evaluation of PA of the three trimesters. Participants were asked to wear accelerometer during the first (10–14 weeks), second (20–24 weeks), and third trimesters (30–34 weeks) for seven consecutive days (including five weekdays and two weekend days) which recorded as T1, T2 and T3. Elastic belt was used to secure accelerometer to right hip for whole day and removed while sleeping and watering activities. Wearing accelerometer more than 10 hours each day was considered as an effective day, and effective days more than five days (at least including four weekdays and one weekend day) were considered as valid data. Accelerometer data were downloaded and analyzed using the Actilife 6.13.3 software (Actigraph Inc., Pensacola, FL, USA). Accelerometer data were integrated through Actilife 6.13.3 software and output as acceleration count (counts per minute, CPM). Zero count recorded by accelerometer for 60 minutes or more was considered as not worn and excluded from the analysis. The cut-off point of Freedom was used to divide PA into four categories: sedentary time (ST) (< 100 CPM), light physical activity (LPA) (100–1951 CPM), moderate physical activity (MPA) (1952–5724 CPM), and vigorous physical activity (VPA) (≥ 5725 CPM) [7].

Participants were divided into vaginal delivery group and cesarean delivery group. The differences of PA between the two groups in the three trimesters were compared, and the effects of PA on the mode of delivery were analyzed.

Statistical analysis

The SPSS 19.0 software (IBM Corp, Armonk, NY, USA) was used for statistical analysis. Categorical variables were expressed as values or percentages and compared using a chi square test or Fisher's exact test. Continuous variables with normal distribution were expressed as mean ± SD (standard deviation, SD) and analyzed

using an independent t-test. Receiver operator characteristic curve (ROC curve) was used to determine the cut-off point of PA on the incidence of cesarean delivery. The PA cut-off points with a significance value of $p < 0.05$ were classified according to ROC analysis. Binary logistic regression was performed to analyze the association between the cut-off points of PA and the mode of delivery. The model was adjusted for age, pre-pregnancy BMI, history of cesarean section and way of conception and expressed as adjusted odds rate (aOR) and 95% confidence interval (95% CI). AP value of < 0.05 was considered statistically significant.

RESULTS

There were 228 cases recruited in this study. There were 31 participants withdrew (16 in first trimester, four in second trimester, and 11 in third trimester). Finally, 197 pregnant women participated in the study (Fig. 1). There were 120 cases (60.9%) in vaginal delivery group and 77 (39.1%) in cesarean delivery group. The proportion of cases ≥ 35 years in cesarean delivery group was higher than vaginal delivery group (14.3% vs 4.2%; $p = 0.011$). There were 139 primipara (70.6%) and 58 multipara (29.4%). There was no difference in BMI before pregnancy, education, income, smoking, and parity between the two groups (Tab. 1).

The differences of PA between the two groups of the three trimesters were presented in Table 2. MPA was longer in vaginal delivery group than cesarean delivery group in the first and second trimester (27.5 vs 21.5 min/day, $p = 0.006$; 26.8 vs 19.4 min/day, $p = 0.001$). There were no differences in LPA and ST between the two groups in the first and the second trimester; however, LPA was longer in vaginal delivery group than cesarean delivery group (217.3 vs 195.9 min/day; $p = 0.006$) and ST was lesser in vaginal delivery group than cesarean group in the third trimester (529.1 vs 551.7 min/day; $p = 0.041$). VPA in the two groups was rare in all three trimesters (< 0.1 min/day) and was not comparable between both groups.

Table 3 shows the ROC analysis results of PA cut-off points on the rate of cesarean delivery. The PA cut-off points for the rate of cesarean delivery were

analyzed using ROC analysis with vaginal delivery as the state variable. The cut-off point of MPA in the first trimester was 37.8 min/day [area under the curve (AUC) = 0.59; p = 0.024] and second trimester was 17.9 min/day (AUC = 0.63, p = 0.002). The cut-off point of LPA in the third trimester was 201.0 min/day (AUC = 0.61; p = 0.009) and that of ST in the third trimester was 552.6 min/day (AUC = 0.59; p = 0.035). ST and LPA in the first and second trimesters did not have cut-off points (p > 0.05).

Table 4 illustrates the influence of PA on the risk of cesarean delivery. Considering vaginal delivery group as reference, after adjusting for age, pre-pregnancy BMI, parity and history of cesarean section, binary logistic regression analysis showed that women with MPA < 37.8 min/day increased the risk of cesarean delivery compared to cases with MPA ≥37.8 min/day in first trimester (aOR 2.62; 95% CI 1.09 to 6.32; p = 0.031). Compared to women with MPA ≥ 17.9 min/day, participants with MPA < 17.9 min/day in the second trimester increased the risk of cesarean delivery (aOR 3.01; 95% CI 1.57 to 5.75; p = 0.001). ST and LPA during pregnancy did not increase or decrease the risk of cesarean delivery (p > 0.05).

Discussion

Lack of PA is known to be a risk factor for many adverse outcomes. This study analyzes the impact of PA on delivery model of singleton pregnant women, which is of great significance to pregnant women's physical and mental health and safe delivery.

There were few studies on the difference between vaginal and cesarean delivery of the three trimesters. A prospective study from Baena-García et al. used triaxial accelerometer to monitor PA for seven consecutive days in the second trimester of 94 cases and results showed that ST was shorter while the LPA and MPA were longer in vaginal delivery group compared to the cesarean delivery group, but no difference (ST 503.3 vs 542.2 min/day; LPA 2800.0 vs 2617.1 min/week and MPA 255.4 vs 237.8 min/week, p > 0.100) [8]. The researchers only assessed PA and ST in the second trimester; their results could not represent the entire pregnancy. A prospective study

by Ko et al. using questionnaire to evaluate PA of 150 primipara and showed that total PA in spontaneous delivery group was longer than unplanned cesarean group (38.76 vs 29.60 hour/week; p = 0.04) [9]. However, the authors used questionnaire to evaluate PA and did not analysis the differences of different types of PA between the two groups. Our results showed that MPA was longer in the vaginal delivery group than in the cesarean delivery group in the first and second trimesters (27.5 vs 21.5 min/day, p = 0.006; 26.8 vs 19.4 min/day, p = 0.001, respectively). LPA in the third trimester was longer in the vaginal delivery group than the cesarean group (217.3 vs 195.9 min/day; p = 0.006). These results are different from those of other studies. Our results showed that there was no significant difference in ST between the two groups in the first two trimesters. However, ST in the third trimester was shorter in the vaginal delivery group than in the cesarean group (529.1 vs 551.7 min/day; p = 0.041). These results indicate that increasing PA in the first two trimesters and decreasing ST in the third trimester could be helpful in increasing the chances of vaginal delivery.

A few studies have explored the effect of PA on the mode of delivery. Sanda et al. conducted a study involving 606 cases divided into intervention group and control group. The results showed that there was no difference in the rate of cesarean delivery between both groups (2.7% vs 2.4%; p > 0.05) [10]. In a study by Ferreira et al., women in the exercise group engaged in PA three times a week for two hours each, from 12–15 weeks of gestation until delivery. No difference in the rate of cesarean delivery was observed between the exercise and control groups (27.3% vs 32.1%; p = 0.418) [11]. However, a meta-analysis from Domenjoz et al. revealed that PA during pregnancy can lower the risk of cesarean delivery (relative risk 0.85; 95% CI 0.73–0.99) [12]. These studies only established intervention measures but did not assess levels of PA in the intervention groups, and they did not compare the difference of PA between control group and intervention group. Tinius et al. utilized telephone interviews to review PA during pregnancy in 96 obese cases and divided them into active and inactive groups. No difference was observed in the rate of cesarean

delivery between the two groups (25.0% vs 31.2%; p = 0.46) [13]. The authors only included obese women. Another study by Koushkie Jahromi et al. using questionnaire to assess PA of 132 women in the third trimester, and showed no difference in the rate of cesarean delivery between exercise and no exercise groups during pregnancy (28.71% vs 30.64%; p = 0.594) [14]. A study by Russo et al. which used questionnaire to evaluate PA of 1313 cases showed that ST in the second and third trimesters increased the risk of cesarean delivery (OR = 1.54, p = 0.05) [15]. A study by Takami et al. used questionnaire to assess PA of 92796 cases during the second and third trimester and noted that the risk of cesarean delivery was higher in the low PA group (OR = 1.07; P = 0.007) [16]. However, Bovbjerg et al. conducted questionnaire via telephone to assess PA of 1205 women at 17–22 weeks and 27–30 weeks of gestation. Their results showed that only total PA at 27–30 weeks was associated with risk of cesarean delivery (β = –0.07, p = 0.049); there was no correlation between moderate-to-vigorous PA and risk of cesarean delivery(p > 0.05) [17]. These studies often used questionnaire to assess PA, with low accuracy and recall bias. Research from Mizgier et al. used triaxial accelerometer to monitor PA of the second trimester of 57 cases. They found no difference in the rate of cesarean delivery between women with MPA > 21.38 min/day and those with MPA < 21.38 min/day (20.69% vs 21.43%; p > 0.05) [18]. But the sample size was small, and they only compared the rate of cesarean delivery. Our study also used triaxial accelerometer to assess PA, but we followed the participants for the three trimesters, and results showed that women with less MPA in the first trimester (aOR 2.62, p = 0.031) and in the second trimester increased the risk of cesarean delivery (aOR 3.01, p = 0.001). These findings indicated that increasing MPA in the first two trimesters would decrease the risk of cesarean section and increase the rate of vaginal delivery. Considering the negative effects of cesarean delivery on maternal and fetal health, this finding had relevant clinical and public health significance. We speculated that increasing MPA from the early pregnancy could reduce the risk of cesarean delivery, mostly because higher MPA would control excessive weight gain during pregnancy and reduce the risk of gestational diabetes

mellitus and macrosomia. But our results showed that ST, LPA and MPA of the third trimester were not associated with cesarean section. This indicated that women only decreased ST and increased PA in the third trimester would not help to change the risk of cesarean delivery.

There were some limitations. First, subgroups of pre-pregnancy BMI were not analyzed because of the sample size, but we adjusted for pre-pregnancy BMI attempted to decrease bias. Second, primipara group were not analyzed separately, but we adjusted for parity and history of cesarean section to decrease the bias. Third, all women were from urban areas, the results maybe not be suitable to rural people.

CONCLUSIONS

Less MPA in the first two trimesters were associated with higher risk of cesarean delivery. Pregnant women should target to increase moderate PA from early pregnancy.

Authors' contributions

Hanqing Chen and Wai-Kit Ming contributed to the concept of this article and the analysis and interpretation of data. Hanqing Chen has composed the article draft. Casper J. P. Zhang provided guidance on data processing and revised the manuscript. Wai-Kit Ming and Zilian Wang raised the idea of this article and contributed to the study design and manuscript revision.

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Conflict of interest

The authors declare that they have no conflict of interests to disclose.

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Table 1. Demographic characteristics of the participants

Characteristics	Vaginal delivery (n = 120)	Cesarean delivery (n = 77)	p
Age (years)			
< 35	115 (95.8%)	66 (85.7%)	
≥ 35	5 (4.2%)	11 (14.3%)	0.011
Pre-pregnancy BMI [kg/m^2]			
< 18.5	29 (24.2%)	13 (16.9%)	
18.5–24.9	85 (70.8%)	54 (70.1%)	0.088
≥ 25.0	6 (5.0%)	10 (13.0%)	
Education			
Less than high school	9 (7.5%)	9 (11.7%)	0.319
Graduate and above	111 (92.5%)	68 (88.3%)	
Income			
Low	66 (55.0%)	36 (46.8%)	0.258
High	54 (45.0%)	41 (53.2%)	
Smoking before pregnancy			
Yes	4 (3.3%)	1 (1.3%)	0.650
No	116 (96.7%)	76 (98.7%)	
Conception way			
IVF	13 (10.8%)	16 (20.8%)	0.055
Normal	107 (89.2%)	61 (79.2%)	

Parity			
0	85 (70.8%)	52 (67.5%)	0.623
1	35 (29.2%)	25 (32.5%)	

Categorical variables were expressed as values or percentages and compared with a chi square test or Fisher's exact test

BMI — body mass index; IVF — in-vitro fertilization

Table 2. Differences in PA between vaginal delivery and cesarean delivery group

PA		Vaginal delivery (n = 120)	Cesarean delivery (n = 77)	p
T1	ST (min/d)	546.3 ± 77.7	555.0 ± 72.8	0.429
	LPA (min/d)	213.6 ± 64.7	203.9 + 55.7	0.280
	MPA (min/d)	27.5 ± 17.6	21.5 ± 13.2	**0.006**
T2	ST (min/d)	537.3 ± 74.0	541.9 ± 68.5	0.661
	LPA (min/d)	214.6 ± 65.2	206.7 ± 49.5	0.336
	MPA (min/d)	26.8 ± 18.4	19.4 ± 12.3	**0.001**
T3	ST (min/d)	529.1 ± 76.5	551.7 ± 73.7	**0.041**
	LPA (min/d)	217.3 ± 60.6	195.9 ± 46.8	**0.006**
	MPA (min/d)	23.3 ± 16.5	19.4 ± 14.2	0.088

Continuous variables with normal distribution were expressed as mean standard deviation and analyzed with an independent t-test

LPA — light physical activity; MPA — moderate physical activity; PA — physical activity; SD — standard deviation; ST — sedentary time; T1 — first trimester; T2 — second trimester; T3 — third trimester

Table 3. The receiver operator characteristic curve analysis of physical activity cut-off on cesarean section rate

Trimester	T1			T2			T3		
PA	ST	LPA	MPA	ST	LPA	MPA	ST	LPA	MPA
AUC	0.49	0.54	0.59	0.48	0.51	0.63	0.59	0.61	0.57
P value	0.872	0.324	0.024	0.662	0.74	0.002	0.035	0.009	0.087
95% CI									
Lower	0.41	0.46	0.51	0.40	0.43	0.55	0.52	0.53	0.49
Upper	0.58	0.62	0.67	0.57	0.6	0.70	0.66	0.68	0.66

AUC — area under curve; CI — confidence index; LPA — light physical activity; MPA — moderate physical activity; PA — physical activity; ST — sedentary time; T1 — the first trimester; T2 — the second trimester; T3 — the third trimester

Table 4. Binary logistics regression analysis of PA in the three trimesters on the risk of cesarean delivery

Trimesters	PA	aOR*	95% CI	P-value
T1	ST	1.00	0.99–1.01	0.780
	LPA	1.00	0.99–1.01	0.813
	MPA ≥ 37.8 min/d[b]	2.62	1.09–6.32	0.031
T2	ST	1.00	0.99–1.01	0.690
	LPA	1.00	0.99–1.01	0.527
	MPA ≥ 17.9 min/d[c]	3.01	1.57–5.75	0.001
T3	ST ≥ 552.6 min/d[d]	1.53	0.79–2.96	0.207
	LPA ≥ 201.0 min/d[e]	1.78	0.87–3.62	0.112
	MPA	0.99	0.97–1.01	0.219

* adjusted age, pre-pregnancy BMI, way of conception and parity

[b]MPA ≥ 37.8 min/d in the first trimester as reference; [c]MPA ≥ 17.9 min/d in the second trimester as reference; [d]ST ≥ 552.6 min/d in the third trimester as reference; [e]PA ≥ 201.0 min/d in the third trimester as reference

CI — confidence index; LPA — light physical activity; MPA — moderate physical activity; OR — odds rate; PA — physical activity; ST — sedentary time

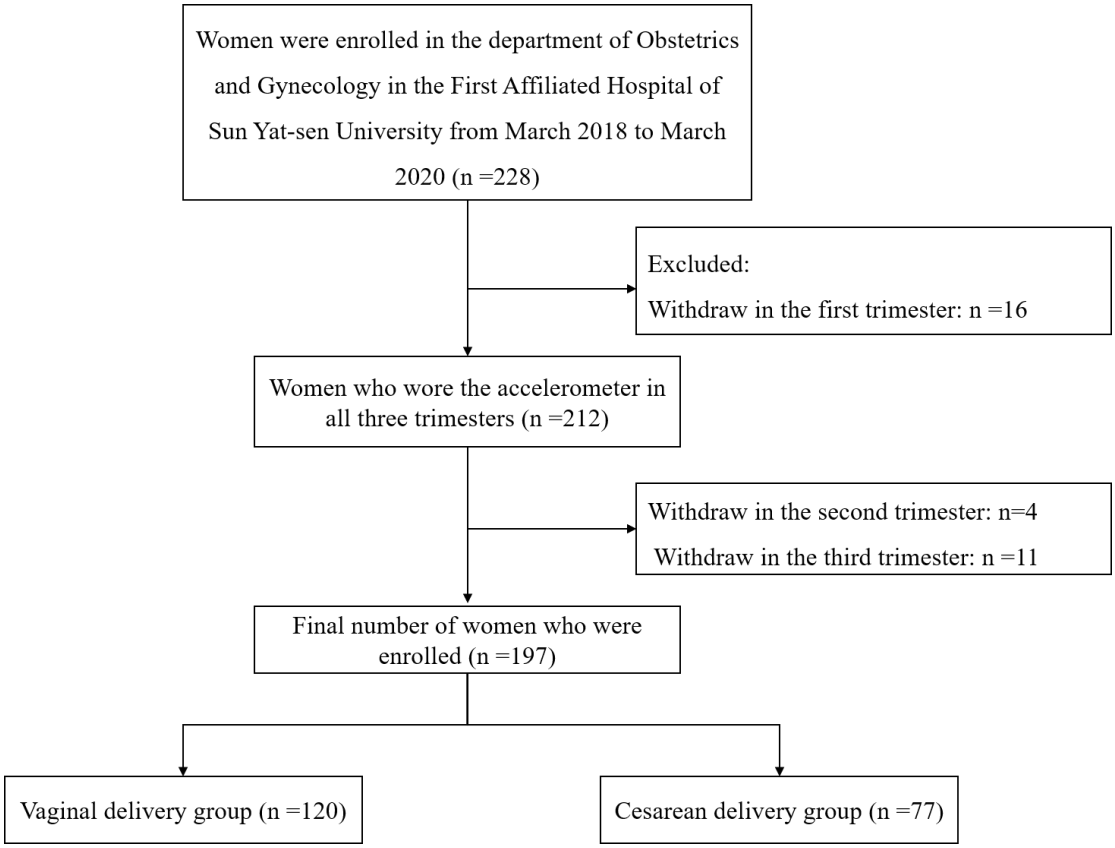

Figure 1. Flow chart of the enrollment process