International Journal of Women's Health

Dovepress
Taylor & Francis Group

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ORIGINAL RESEARCH

Trajectories and Predictors of Physical Activity in Women with Gestational Diabetes Mellitus in Guangzhou, China: A Prospective Study

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Purpose: This study analyzed physical activity (PA) trajectories, identified subgroups, and explored their associations in women with gestational diabetes mellitus (GDM).

Methods: From January to November 2024, a longitudinal study was conducted using convenience sampling to recruit women with GDM from a maternal and child health hospital in Guangzhou (China). General information and baseline PA data were collected at diagnosis (24–26 weeks of gestation), and follow-up PA assessments were carried out at 28, 32, and 36 weeks. The Pregnancy Physical Activity Questionnaire (PPAQ) was used to assess PA levels. The latent class growth model (LCGM) identified distinct PA trajectories.

Results: Of the 236 women enrolled, 223 completed follow-up. PA scores increased from T0 to a peak at T1 (median 156.45 MET·h/w, IQR: 113.08–221.10), then declined to a low at T3 (114.63 ± 47.30 MET·h/w). LCGM identified three trajectory subgroups: high-level reduction (4.04%), moderate-level fluctuation (43.50%), and low-level stable (52.47%). Ordinal logistic regression showed that unemployment (odds ratio (OR): 4.754; 95% confidence interval (CI): 1.878–12.037) and exercising alone (OR: 2.268; 95% CI: 1.219–4.225) were significantly associated with subgroup membership ($P<0.05$).

Conclusion: PA levels in women with GDM initially rose and then declined, with most sustaining stable low activity. Unemployment and solitary exercise were significant predictors of lower PA trajectories.

Keywords: gestational diabetes mellitus, physical activity, latent class growth model, longitudinal study

Introduction

Globally, physical activity (PA) during pregnancy has emerged as a significant public health concern. A growing international consensus from major health bodies, including the International Federation of Gynecology and Obstetrics (FIGO) [1] and the 2019 Canadian Guidelines for Physical Activity During Pregnancy,[2] highlighted the critical health benefits of exercise for pregnant women.

Gestational diabetes mellitus (GDM) is one of the most prevalent challenges during pregnancy, which is defined by reduced glucose tolerance initially detected during pregnancy without pre-existing diabetes. With improving living standards and changing diagnostic criteria, GDM prevalence has climbed to 15–20% globally and 18.9% in China.[3] GDM poses significant risks for both mothers and babies. Excessive fetal pancreatic β-cell proliferation can lead to premature release of non-physiological adult insulin level,[4] which may result in complications, such as premature delivery, dystocia, macrosomia, and newborn hypoglycemia. More critically, GDM increases the likelihood of developing type 2 diabetes mellitus postpartum, which can have long-term adverse effects on the mother's health. As a result, GDM has become a major concentration for healthcare professionals.

Notably, PA refers to any energy-consuming movement, resulting from skeletal muscle contraction, including both structured exercise and routine activities, such as housework, work, and leisure. PA enhances basal metabolic rate, improves blood circulation, and supports maternal health during pregnancy. However, studies both locally and

Received: 19 August 2025
Accepted: 13 November 2025
Published: 25 November 2025

internationally have shown that PA level in pregnant women decreases with advancing gestational age.[5,6] Low maternal PA is associated with adverse maternal and fetal outcomes. For instance, Ren et al found that excessive gestational weight gain increased the risk of preeclampsia by 92%,[7] while Sridhar et al reported a 46% higher incidence of obesity in children of mothers with significant weight gain during pregnancy.[8] PA reaches its lowest level in the third trimester, potentially reducing intestinal motility and contributing to constipation.[9] Additionally, decreased engagement of pelvic, lumbar, and abdominal muscles may increase the likelihood of cesarean delivery.[10]

Women with GDM may may experience greater benefits from PA. In this cohort, PA controls gestational weight gain, improves skeletal muscle glucose absorption, and enhances pancreatic β-cell insulin production. Improved insulin sensitivity and glycemic balance can be partly attributed to the enhanced GLUT-4 expression and activity.[11] Thus, PA is crucial to alleviate GDM pregnancy-associated complications.

Under normal physiological conditions, insulin resistance increases during the second and third trimesters due to the elevated levels of estrogen, progesterone, and other antagonistic insulin-like substances. Insulin resistance rises rapidly, reaching its highest rate at 28 weeks, peaking at 32 weeks, and stabilizing by 36 weeks.[12] For women with GDM, this physiological change is not adequately compensated, leading to the elevated blood glucose level.[13] Follow-up visits at 28, 32, and 36 weeks of gestation were scheduled to assess the dynamic effects of PA on glycemia during these critical periods of insulin resistance change.

Previous research has demonstrated that women with GDM may receive increased health guidance, which can enhance their motivation to adopt healthier behaviors and influence their level of PA.[14] Although previous studies have described general PA trends in pregnant women, few have specifically examined the heterogeneity of PA patterns among women with GDM using longitudinal, person-centered approaches, such as Latent Class Growth Modeling (LCGM). This study aimed to identify distinct PA trajectories and their predictors in women with GDM, providing a basis for personalized interventions. Changes in PA can significantly vary among individuals due to different physiological, psychological, and social factors. Therefore, the LCGM[15] was employed to identify distinct PA trajectories and determine the optimal model representing activity patterns in this group. This can help to guide the timely discovery of interventional targets in clinical practice and provide a basis for personalized interventions for women with GDM.

Materials and Methods

Study Design and Sampling

According to the longitudinal study design, the convenience sampling method was employed to recruit participants from the obstetrics department of a maternal and child health hospital located in Guangzhou (China) between January and November 2024. Women with GDM who met the inclusion criteria and consented to participate were recruited for the study. They were invited to attend a face-to-face interview, during which the study's objectives and procedures were thoroughly explained.

Inclusion and Exclusion Criteria

Inclusion criteria were as follows: ① Women diagnosed with GDM for the first time based on the oral glucose tolerance test (OGTT) performed between 24 and 26 weeks of gestation; ② Age over 20 years old; ③ Singleton pregnancy; ④ Signing the informed consent form, voluntarily participating in the study, attending regular outpatient visits, and being able to comply with follow-up requirements.

Exclusion criteria were as follows: ① Presence of other pregnancy complications or serious underlying diseases (eg, cardiovascular disease, hepatic or renal insufficiency); ② Presence of severe fetal abnormalities or contraindications to exercise, as defined by the *2022 Guidelines for the Diagnosis and Treatment of Hyperglycemia in Pregnancy*,[16] including but not limited to cervical insufficiency (cervical tube length≤25 mm measured by transvaginal ultrasound in the second trimester, or the cervix was funnel-shaped dilatation), vaginal bleeding (bright red color, with blood clots, more volume), fetal growth restriction (fetal weight/abdominal circumference < 3rd percentile or absence of umbilical artery diastolic blood flow; when fetal weight/abdominal circumference was < 10th percentile, umbilical artery pulsatility index was > 95th percentile and/or uterine artery pulsatility index was > 95th percentile); ③ Pre-existing diagnosis of type 1 or type 2 diabetes mellitus prior to pregnancy; ④ Presence of mental illness, impaired consciousness, or cognitive dysfunction.

Withdrawal criteria were as follows: ① Abortion or termination of pregnancy during the study; ② Loss to follow-up due to missing data at two or more time points. As this study involved three follow-up assessments, participants were considered lost to follow-up if they transferred to other hospitals or could not be contacted at least twice via prenatal visits, telephone, or other tools, resulting in insufficient data collection. When the missing data rate exceeds 60%, the effectiveness of any imputation method is significantly reduced, compromising data integrity and the reliability of analysis results;[17] ③ Voluntary withdrawal from the study at any time for personal reasons.

Determination of Sample Size

In this study, a total of 4 repeated measurements were performed on each subject. According to the sample size estimation table for single-group repeated measures design proposed by Lu[18] in 2008, the average correlation coefficient was set at p = 0.50, the effect size at f = 0.14, and the significance level at α = 0.05. Under these parameters, the required sample size was at least 142. Consequently, as longitudinal studies are typically prone to sample loss, this study accounted for a 15% loss to follow-up rate (reference was made to the 20.3% sample dropout in the study conducted by Lee et al[5]), resulting in a required sample size of at least 230 participants.

Survey Time

The investigation timeline was based on the pattern of insulin resistance changes during pregnancy, where insulin resistance rapidly increased, reaching its highest rate at 28 weeks, peaked at 32 weeks, and stabilized by 36 weeks.[5] As insulin resistance increases, maternal glucose utilization and conversion decrease, leading to the elevated blood glucose level. PA can enhance glucose uptake and utilization by skeletal muscle cells, maintaining glucose stability. Therefore, follow-up visits at 28, 32, and 36 weeks of gestation were scheduled to assess the dynamic effects of PA on glycemia. Follow-ups occurred at 28, 32, and 36 weeks to match insulin resistance peaks in GDM.

Research Tools

General Information Questionnaire

In this study, a general information questionnaire was developed based on the literature review of the influential factors of PA in pregnant women. The purpose was to investigate the social demographic data (including age, occupation, educational level, menstrual and reproductive history, gestational age, height, pre-pregnancy and current weight, etc) and pre-pregnancy exercise status of GDM women. To ensure content validity of the questionnaire, an obstetrician and an endocrinologist were invited to review the general information questionnaire, and they assessed the relevance and clarity of each item. The general information questionnaire was subsequently tested in 20 women with GDM to assess its readability and feasibility. All women who participated in the test were able to understand and select appropriate answers according to their individual circumstances, and the test phase confirmed that the general information questionnaire was appropriate for use in this study.

Pregnancy Physical Activity Questionnaire (PPAQ)

This questionnaire was designed by Chasan et al[19] to measure pregnant women's PA levels. The Chinese version of PPAQ was adapted for the local context by Zhang et al.[20] It has demonstrated notable reliability and validity, with a content validity index of 0.940 and test-retest reliability of 0.944. The questionnaire consists of 31 items, including 14 on housework, 4 on transportation, 8 on sports and exercise, and 5 on occupational activities. Each activity is classified by its metabolic equivalent of task (MET) into sedentary, low-, moderate-, or vigorous-intensity PA. MET values were assigned to each activity based on the standardized Compendium of Physical Activities.[21] Weekly energy expenditure for each activity is calculated based on its MET value and reported frequency. Total energy expenditure is obtained by summing across all activities. In this study, the frequency of participation was calculated using the mean of the response options,[22] and the duration of each categorical response was assigned a specific value to compute weekly energy expenditure (MET·h/week).[21]

A systematic approach was applied to assign time values to categorical response options, aiming to optimize measurement precision while preserving clinical relevance. For infrequent activity, conservative estimates were used ("never"= 0 h, "<0.5h/ day"= 0.25 h) to minimize overestimation of the lowest activity. For more frequent activity categories (eg, 0.5--1 h/day = 0.75 h; 1--2 h/day = 1.5 h; 2--3 h/day = 2.5 h), midpoint values were assigned to best reflect the central tendency of reported behaviors in the pregnant population. For the highest category (>3 h/day), a fixed value of 3 h was used as a reasonable upper limit to reduce overestimation bias, considering physiological constraints in the third trimester and activity patterns in the study cohort. This standardized value assignment was consistently applied across all participants and activity types to ensure comparability, following established methodology in PA studies during pregnancy.

Data Collection

Participants who met the inclusion and exclusion criteria were selected to complete the general information questionnaire and PA questionnaire during pregnancy on the day of their first diagnosis of GDM. They were followed up at 28, 32, and 36 gestational weeks to complete the PA questionnaire. To ensure data objectivity, all interviewers underwent standardized training to maintain a neutral attitude during face-to-face interviews, strictly avoiding leading questions or emphasizing specific responses related to PA levels. Importantly, interviewers were not informed about the study's specific hypotheses regarding PA trajectories or subgroup analyses during data collection. The research team accessed and analyzed the data only after all participant interviews were completed, thereby minimizing the risk of interviewer bias influencing the follow-up assessments. This approach, combined with the structured format of the PPAQ, helped ensure the reliability of the data collection process.

Quality Control

Before the survey, researchers thoroughly familiarized themselves with the study protocol, standardized the instructions, and conducted simulated training sessions. During data collection, participants who met the inclusion and exclusion criteria were informed of the study's purpose, significance, procedures, and data confidentiality, as well as the non-invasive nature of the survey. Upon obtaining informed consent, researchers administered paper-based questionnaires through face-to-face interviews. Standardized instructions were provided to guide questionnaire completion. Completed questionnaires were immediately reviewed for missing items, and only fully completed ones were collected. After each survey, two researchers independently entered the data and cross-verified the entries to ensure accuracy, particularly concentrating on attention to the completeness and integrity of the original data. After the two researchers entered the data independently, the consistency between corresponding entries was automatically verified through item-by-item formulaic comparison. Any discrepancies detected were resolved by cross-referencing the original printed questionnaires for verification and correction.

Statistical Analysis

All data were entered into an Excel spreadsheet by two team members and cross-checked for consistency prior to statistical analysis, which was conducted by SPSS 25.0 software (IBM, Armonk, NY, USA). Missing values were handled using mean imputation, as the missing rates at T1, T2, and T3 were 1, 3, and 13, respectively, each less than 10% of the total sample, meeting standard thresholds for acceptable imputation. A sensitivity analysis was conducted by reanalyzing the data after excluding participants lost to follow-up, with no remarkable changes in results. Following the approach used by Shan et al,[23] the sensitivity analysis results were summarized narratively to avoid excessive tabular content in the manuscript. The significance level was set at α=0.05. Participants' baseline characteristics, particularly those who completed follow-up and those who dropped out, were compared. Categorical data were presented as frequency and percentage. Normally distributed continuous data were expressed as mean ± standard deviation, and abnormally distributed data were presented as median and interquartile range. Descriptive analysis was conducted on participants' PA levels at different gestational weeks.

LCGM was applied to analyze PA trajectories across gestational weeks, and Mplus 8.7 was used for model fitting to determine the optimal trajectory model. The model fit was assessed using several indicators, including the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), sample-adjusted BIC (aBIC), Entropy, the Lo-Mendell-Rubin likelihood ratio test (LMR), and the bootstrapped likelihood ratio test (BLRT). Lower values for AIC, BIC, and aBIC indicated a better model fit. An entropy value closer to 1 reflected higher classification accuracy. A significant *P*-value (<0.05) for the LMR and BLRT suggested that the k-class model was a better fit than the *k-1* class model. Model selection was based on the following criteria: lower AIC, BIC, and aBIC values indicated better fit; Entropy values closer to 1 reflected higher classification accuracy; and significant LMR and BLRT results ($P < 0.05$) suggested that the model with *k* classes was a significant improvement over the model with *k-1* classes. LCGM identifies latent subgroups within a population that follow similar longitudinal patterns, promoting the detection of distinct trajectory classes with heterogeneous development over time. Factors influencing PA trajectories were explored using univariate analysis (Chi-square or Fisher's exact tests) and multivariate analysis via ordinal logistic regression.

Ethical Approval and Informed Consent

The study protocol was approved by the Ethics Committee of Guangdong Women and Children Hospital (Approval No. 202401007). The study complies with the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment, with a clear explanation of study procedures, voluntary participation, and data confidentiality measures. All data were anonymized to protect participant privacy in accordance with ethical guidelines.

Results

Participants' Characteristics

A total of 236 participants were initially enrolled in this study. During follow-up, 13 cases were lost, including 11 due to loss of contact by 32 weeks, and 2 due to hospital transfer for delivery by 36 weeks. Ultimately, 223 participants were included in the analysis, yielding an overall attrition rate of 5.51%. The Flowchart of the participants' selection was shown in Figure 1 for details. The median age in the Follow-up group was 31 years, the median height was 1.58 (m), and the median weight was 61.1 (kg). The excluded group had a median age of 29 years, a median height of 1.56 (m), and a median weight of 58.1 (kg). No significant differences ($P>0.05$) were found in baseline characteristics between participants who completed follow-up and those who were excluded due to attrition, as detailed in Table 1.

Assessment of PA Levels Across Gestational Weeks

The total PA scores of women with GDM exhibited an initial increase, followed by a subsequent decline throughout gestation. Specifically, scores exhibited an upward trend from T0 to T1, peaking at T1, then gradually decreased from T1 to T3, reaching their lowest level at T3. Regarding activity components, household activity scores increased from T0 to T1 and then declined from T1 to T2. Travel/transportation activity scores exhibited a continuous increase from T0 to T3,

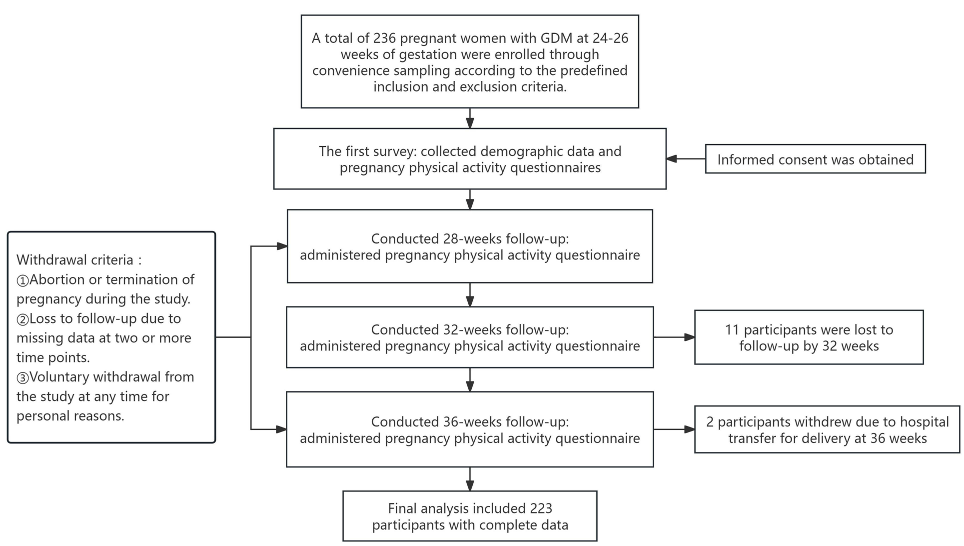

Figure 1 Flowchart of the participants' selection.

Table 1 Participants' Characteristics in Completed Follow-up and Excluded Groups (n=236)

Variable		Follow-up Group (n=223)	Excluded Group (n=13)	Z/x^2	*P*-value
Age (years)		31.00 (28.00, 34.00)	29.00 (26.00, 32.50)	−1.478	0.139[a]
Height (m)		1.58 (1.54, 1.62)	1.56 (1.53, 1.61)	−0.919	0.358[a]
Weight (kg)		61.10 (56.80, 68.00)	58.10 (55.30, 65.90)	−1.294	0.196[a]
Pre-pregnancy BMI (kg/m^2)		21.64 (20.23, 24.03)	20.43 (19.44, 21.87)	−1.845	0.065[a]
Income (yuan/month)	2000–5000	24 (10.8)	4 (30.8)	4.114	0.111[b]
	5001–8000	101 (45.3)	5 (38.5)		
	>8000	98 (43.9)	4 (30.8)		
Education	≤High school or below	38 (17.0)	4 (30.8)	2.793	0.273[b]
	Associate degree	70 (31.4)	5 (38.5)		
	≥Bachelor's degree	115 (51.6)	4 (30.8)		
Occupation	Unemployed	51 (22.9)	7 (53.8)	5.532	0.114[b]
	Government/Public institution staff	24 (10.8)	1 (7.7)		
	Private enterprise employee	94 (42.2)	4 (30.8)		
	Others	54 (24.2)	1 (7.7)		
Family history of diabetes	Yes	46 (20.6)	1 (7.7)	-	0.474[b]
	No	177 (79.4)	12 (92.3)		
Number of pregnancies	First	122 (54.7)	6 (46.2)	2.830	0.252[b]
	2 times	59 (26.5)	2 (15.4)		
	≥3 times	42 (18.8)	5 (38.5)		
History of adverse pregnancy	None	157 (70.4)	8 (61.5)	1.001	0.515[b]
	Miscarriage	53 (23.8)	4 (30.8)		
	Others	13 (5.8)	1 (7.7)		
Number of deliveries	None	156 (70.0)	10 (76.9)	3.108	0.180[b]
	1 time	63 (28.3)	2 (15.4)		
	≥2 times	4 (1.8)	1 (7.7)		
Exercise frequency before pregnancy	≥3 times/week	11 (4.9)	2 (15.4)	5.949	0.088[b]
	1–2 times/week	45 (20.2)	0 (0.0)		
	1–2 times/month	120 (53.8)	7 (53.8)		
	Never	47 (21.1)	4 (30.8)		
Exercise duration before pregnancy	<30 minutes	129 (57.8)	8 (61.5)	2.735	0.256[b]
	30-60 minutes	90 (40.4)	4 (30.8)		
	≥60 minutes	4 (1.8)	1 (7.7)		
Exercise companion	None	101 (45.3)	9 (69.2)	2.829	0.093[c]
	Family/others	122 (54.7)	4 (30.8)		

Note: Wilcoxon rank-sum test[a]; Fisher's exact test[b]; Chi-square test[c].

peaking at T3. In contrast, recreational/exercise and work-related activity scores rose from T0 to T1 and subsequently declined from T1 to T3. Further details are presented in Table 2.

Model Fit Indices for PA Trajectories

This study employed LCGM to analyze PA trajectories across gestational weeks using total activity scores from women with GDM. Using Model 2 as the baseline, the number of trajectory classes was progressively elevated, and models with 2 to 5 trajectories were systematically compared. Although Models 2 and 5 exhibited lower entropy values than Model 3, the higher entropy of Model 3 indicated superior classification accuracy. Additionally, Model 3 showed superior fit compared with Model 2, as evidenced by lower AIC, BIC, and aBIC values. When Model 4 was compared with Model 3, the non-significant LMR test ($P > 0.05$) suggested no statistically significant improvement. Consequently, Model 3 was selected as the optimal trajectory model for PA patterns. Additional details are presented in Table 3. The detailed

Table 2 Physical Activity Levels Across Gestational Weeks (MET·h/Week)

Physical Activity Scores	Time			
	T0	T1	T2	T3
Total score	123.90 (79.63, 164.50)	156.45 (113.08, 221.10)	141.08 (106.25, 191.33)	114.63±47.30
Household activities	56.70 (36.40, 77.00)	68.95 (49.00, 88.20)	62.23±26.06	62.26±30.43
Transportation & commuting	11.38 (6.13, 23.63)	14.88 (9.63, 25.38)	16.63 (9.63, 25.38)	18.38 (11.38, 25.38)
Leisure-time exercise	2.63 (0.00, 8.75)	24.00 (11.75, 37.75)	24.00 (14.25, 36.75)	14.25 (6.38, 25.50)
Work-related activities	52.50 (0.00, 66.50)	63.00 (0.00, 80.50)	40.25 (0.00, 66.50)	12.78 (0.00, 24.50)

Note: Time points: T0 (baseline, 24–26 weeks), T1 (28 weeks), T2 (32 weeks), T3 (36 weeks).

Table 3 Model Fit Indices for Physical Activity Trajectories (n=223)

Model	AIC	BIC	aBIC	Entropy	*P* (LMR)	*P* (BLRT)	Probability of class membership (%)
2	9443.346	9474.011	9445.489	0.879	0.0004	<0.001	44.84/55.16
3	9371.323	9412.209	9374.179	0.921	0.0005	<0.001	4.04/43.50/52.47
4	9341.642	9392.750	9345.213	0.859	0.2227	<0.001	25.11/31.39/3.59/39.91
5	9326.279	9387.608	9330.564	0.885	0.0135	<0.001	0.45/3.14/38.12/25.11/33.18

Abbreviations: AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; aBIC, adjusted Bayesian Information Criterion; LMR, Lo-Mendell-Rubin likelihood ratio test; BLRT, Bootstrap likelihood ratio test.

trajectory patterns of Model 3 are illustrated in Figure 2, in which the X-axis represents time points from T0 to T3 (T0: 24–26 gestational weeks at initial survey; T1: 28 weeks; T2: 32 weeks; T3: 36 weeks) and the Y-axis indicates total PA scores. Class 1 comprised 9 cases (4.04%), demonstrating consistently higher activity scores than other classes throughout T0-T3 with a gradual decline over time, which was thus labeled as "high-level decreasing". Class 2 included 97 cases (43.50%), exhibiting moderate activity levels characterized by an initial increase from T0 to T1, followed by a gradual decrease from T1 to T3, which was designated as "moderate-level fluctuating". Class 3 consisted of 117 cases (52.47%),

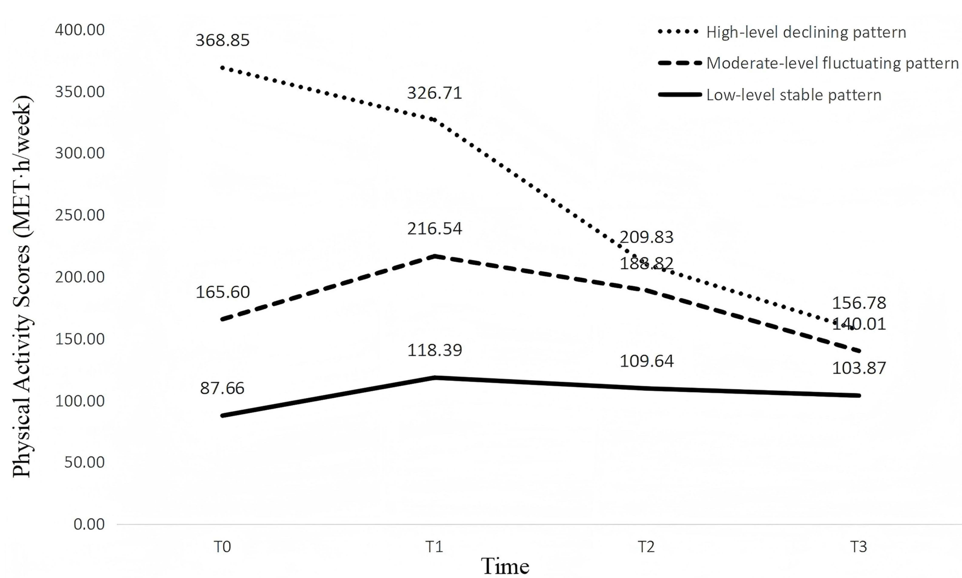

Figure 2 Physical Activity Trajectories Based on Model 3.

exhibiting relatively low but stable activity levels with minimal increase from T0 to T1 and slight decrease from T1 to T3, which was categorized as "low-level stable".

Univariate and Multivariate Analyses of PA Trajectory Groups

Univariate analysis was performed using non-parametric tests, the Chi-square test, or Fisher's exact test based on data type to examine differences among PA trajectory subgroups in women with GDM. The results revealed statistically significant differences (P<0.05) in current weight, pre-pregnancy BMI, occupation, pre-pregnancy exercise frequency, and exercise companions among the three subgroups (Table 4). Variables showing statistical significance in the univariate analysis were included as independent variables in the multivariate analysis. The parallel lines test was satisfied (χ^2=8.003, P=0.534), supporting the usage of ordinal logistic regression. Trajectory subgroups (high-level decreasing, moderate-level fluctuating, and low-level stable) were treated as the dependent variable, and the low-level stable group was set as the reference. The ordinal logistic regression model was statistically significant (χ^2=51.547, P<0.001), and occupation and exercise companions were identified as significant predictors of subgroup membership (P<0.05). Additional data are presented in Table 5.

Table 4 Single-Factor Analysis (n=223)

Variable		High-Level Decreasing (n=9)	Moderate-Level Fluctuating (n=97)	Low-Level Stable (n=117)	Z/x^2	*p*-value
Age (years)		30.00 (27.50, 32.00)	32.00 (28.00, 35.00)	31.00 (28.00, 33.50)	2.384	0.304[a]
Height (m)		1.59 (1.55, 1.62)	1.58 (1.55, 1.63)	1.58 (1.54, 1.61)	2.219	0.330[a]
Weight (kg)		66.20 (61.90, 69.55)	62.50 (57.25, 71.30)	59.50 (55.40, 66.80)	7.306	0.026[a]
Pre-pregnancy BMI (kg/m^2)		23.11 (21.45, 24.46)	22.21 (20.64, 25.10)	21.03 (19.89, 23.24)	11.381	0.003[a]
Income (yuan/month)	2000–5000	1(11.1)	5(5.2)	18(15.4)	7.271	0.102[b]
	5001–8000	4(44.4)	43(44.3)	54(46.2)		
	>8000	4(44.4)	49(50.5)	45(38.5)		
Education	≤High school or below	3(33.3)	11(11.3)	24(20.5)	7.120	0.112[b]
	Associate degree	2(22.2)	28(28.9)	40(34.2)		
	≥Bachelor's degree	4(44.4)	58(59.8)	53(45.3)		
Occupation	Unemployed	1(11.1)	8(8.2)	42(35.9)	28.851	<0.001[b]
	Government/Public institution staff	0(0.0)	15(15.5)	9(7.7)		
	Private enterprise employee	7(77.8)	48(49.5)	39(33.3)		
	Others	1(11.1)	26(26.8)	27(23.1)		
Family history of diabetes	Yes	0(0.0)	22(22.7)	24(20.5)	2.254	0.326[b]
	No	9(100.0)	75(77.3)	93(79.5)		
Number of pregnancies	First	4(44.4)	50(51.5)	68(58.1)	2.385	0.676[b]
	2 times	2(22.2)	28(28.9)	29(24.8)		
	≥3 times	3(33.3)	19(19.6)	20(17.1)		
History of adverse pregnancy	None	5(55.6)	65(67.0)	87(74.4)	5.219	0.234[b]
	Miscarriage	3(33.3)	28(28.9)	22(18.8)		
	Others	1(11.1)	4(4.1)	8(6.8)		
Number of deliveries	None	5(55.6)	69(71.1)	82(70.1)	2.318	0.671[b]
	1 time	4(44.4)	27(27.8)	32(27.4)		
	≥2 times	0(0.0)	1(1.0)	3(2.6)		
Exercise frequency before pregnancy	≥3 times/week	0(0.0)	6(6.2)	5(4.3)	13.037	0.028[b]
	1-2 times/week	5(55.6)	23(23.7)	17(14.5)		
	1-2 times/month	1(11.1)	51(52.6)	68(58.1)		
	Never	3(33.3)	17(17.5)	27(23.1)		
Exercise duration before pregnancy	<30 minutes	7(77.8)	47(48.5)	75(64.1)	7.121	0.113[b]
	30-60 minutes	2(22.2)	48(49.5)	40(34.2)		
	≥60 minutes	0(0.0)	2(2.1)	2(1.7)		
Exercise companion	None	1(11.1)	38(39.2)	62(53.0)	8.437	0.015[b]
	Family/others	8(88.9)	59(60.8)	55(47.0)		

Note: Wilcoxon rank-sum test[a]; Fisher's exact test[b].

Table 5 Ordered Logistic Regression Analysis (n=223)

Variable		Estimate	Standard Error	Wald	*P*-value	OR (95% CI)
Weight		−0.016	0.027	0.345	0.557	0.984 (0.933–1.038)
Pre-pregnancy BMI		−0.112	0.077	2.139	0.144	0.894 (0.769–1.039)
Occupation	Unemployed	1.559	0.474	10.820	0.001	4.754 (1.878–12.037)
	Government/Public institution staff	−0.506	0.511	0.981	0.322	0.603 (0.222–1.640)
	Private enterprise employee	−0.634	0.357	3.149	0.076	0.530 (0.264–1.068)
Exercise frequency before pregnancy	≥3 times/week	0.173	0.730	0.056	0.813	1.189 (0.284–4.973)
	1-2 times/week	−0.596	0.483	1.522	0.217	0.551 (0.214–1.420)
	1-2 times/month	0.128	0.387	0.110	0.740	1.137 (0.532–2.430)
Exercise companion	None	0.819	0.317	6.674	0.010	2.268 (1.219–4.225)

Note: Low-level stable was used as the reference group, trajectory subgroups (high-level decreasing, moderate-level fluctuating, low-level stable) were used as dependent variables, and statistically significant variables in univariate analysis were used as independent variables.

Discussion

This longitudinal study identified three distinct PA trajectories in women with GDM: high-level decreasing (4.04%), moderate-level fluctuating (43.50%), and low-level stable (52.47%). Overall, PA level increased from diagnosis to 28 weeks, then declined, with most women maintaining low activity. Key predictors of lower PA trajectories included unemployment and the lack of exercise companions.

The results showed a trend of initial increase, followed by a gradual decline: PA scores were 123.90 (79.63–164.50) MET·h/w at baseline, peaked at 156.45 (113.08–221.10) MET·h/w at 28 weeks of gestation, declined to 141.08 (106.25–191.33) MET·h/w at 32 weeks, and further decreased to 114.63±47.30 MET·h/w by 36 weeks. These findings are consistent with previous studies in the general pregnant population in China, such as those by Yang et al[24] (122.29 MET·h/week in mid-pregnancy and 125.44 MET·h/week in late pregnancy), Cai et al[25] 112.13 [84.78–148.03] MET·h/week in early to mid-pregnancy), and Zhang et al[26] (142.87 MET·h/week in mid-pregnancy and 140.77 MET·h/week in late pregnancy). However, these scores are markedly lower than activity levels reported in other populations. The Asia-Pacific consensus by Lee et al[5] demonstrated that PA levels in the region are generally higher than those observed in our study, while the American Heart Association advisory by Whitaker et al[27] highlighted concerning patterns of sedentary behavior in the United States that contrast with the active lifestyles found in some other Western populations. For comparison, Chandonnet et al[28] in France (186 MET·h/week in mid-pregnancy and 185 MET·h/week in late pregnancy). These discrepancies may reflect cultural differences in attitudes toward prenatal exercise. In many Western countries, PA during pregnancy is regarded as a component of a healthy lifestyle, and women are actively encouraged to engage in various forms of exercise, such as prenatal yoga, brisk walking, and cycling. For example, Carlsen et al[29] reported that among Norwegian and Swedish pregnant women who exercised at least twice per week, 58.3% chose walking, 35.7% brisk walking, 15.4% cycling, 13.7% strength training, and 5.4% jogging. In contrast, traditional Chinese beliefs often emphasize "fetal stabilization", which encourages limiting PA to avoid potential harm to the fetus. A systematic survey by Tan et al[30] found that only 1.0% of Chinese pregnant women regularly engaged in prenatal exercise, 3.0% participated in other types of PA, and 90.0% reported walking as their primary form of exercise. These findings suggest that PA levels among pregnant women in China, including those with GDM, remain significantly lower than those in Western populations.

More importantly, the present study revealed a distinct pattern in GDM women, including an initial increase in total PA scores from the first survey to 28 weeks of gestation, followed by a gradual decrease from 28 to 36 weeks. Notably, significant increases were found across all domains of PA, such as household chores, transportation, recreational exercise, and work-related activities, during the initial period, and the most significant improvement was notable in recreational exercise. This pattern suggests that women with GDM became more physically active after receiving their diagnosis, likely due to increased awareness of the importance of exercise for managing their condition and improving health outcomes. The diagnosis may serve as a trigger for behavioral change, as women become more conscious of the benefits of PA for glycemic control and maternal-fetal health, leading to increased engagement across multiple activity types.

These findings are consistent with those of previous studies performed by Kaptein et al[14] and Morrison et al,[31] which identified GDM diagnosis as a catalyst for positive lifestyle modifications. Persson et al[32] described this post-diagnosis adaptation as a "process from coma towards balance", wherein women gradually establish a sense of equilibrium between the challenges and benefits of managing GDM. Despite the associated difficulties, the majority of women perceived hyperglycemia as a serious health risk, which in turn motivated proactive lifestyle adjustments, particularly increased PA, to optimize glycemic control and ensure maternal-fetal well-being.[33]

However, the heterogeneity of PA patterns in women with GDM at different gestational weeks was analyzed by LCGM, and three different trajectories were found: high-level reduction (4.04%), moderate-level fluctuation (43.50%), and low-level stable (52.47%). Model 3 was selected as the optimal trajectory model based on fit indices. However, each subgroup comprised between 1%[34] and less than 5%[35] of participants, indicating suboptimal classification. Notably, the low-level stable pattern included the largest proportion of participants and emerged as the dominant trajectory. Although few studies have concentrated specifically on PA in women with GDM, compared with Li et al[6] who reported PA levels of 201.7, 188.6, and 177.2 MET·h/week across trimesters in 249 healthy pregnant women and Yang et al[24] who reported 124.53, 122.29, and 125.44 MET·h/week in 274 healthy pregnant women, revealed that participants in the low-level stable group in the current study maintained consistently lower activity levels: 87.66 MET·h/week at baseline, 118.39 at 28 weeks, 109.64 at 32 weeks, and 103.87 at 36 weeks. These findings highlight the widespread physical inactivity among women with GDM throughout pregnancy. This study contributes to the limited literature by using LCGM to identify heterogeneous PA patterns in women with GDM, providing potential targets for tailored interventions.

In addition, the present study revealed that unemployed women with GDM (OR: 4.754, 95% CI: 1.878–12.037) were significantly more likely to follow the low-level stable PA trajectory compared with their employed counterparts. This finding may be partly attributed to the questionnaire methodology, as unemployed participants consistently scored lower on all five domains of occupational activity. Although these women theoretically had more discretionary time for PA, they paradoxically demonstrated a stronger tendency toward inactivity. This suggests possible gaps in health awareness, motivation, and social support. Unemployed women may lack sufficient understanding of the role of PA in glycemic control, and encouragement is needed to engage in regular exercise. To address this, healthcare providers should implement targeted educational interventions that emphasize the importance of PA in managing blood glucose, aiming to improve health literacy, enhance motivation, and promote active lifestyles in this vulnerable population.[36]

The present study also revealed that GDM women who exercised without companions were more likely to follow the low-level stable PA trajectory versus those with exercise companions (OR: 2.268, 95% CI: 1.219–4.225). This result aligns with findings from Shi et al, Zhang et al, Symons et al, and He et al, emphasizing the notable role of social and family support in promoting PA and self-management behaviors among women with GDM. Shi et al[37] reported positive associations between family support and self-management behaviors, including diet, medication adherence, and PA. Similarly, Zhang et al[38] found that baseline family support significantly predicted both the initial level ($\beta = 0.380$, $P = 0.018$) and rate of improvement ($\beta = 0.747$, $P < 0.001$) in glucose management decision-making behaviors. Moreover, the rate of increase in family support further predicted behavioral progression ($\beta = 0.601$, $P < 0.001$). These studies suggest that enhanced family support improves psychological resilience and self-efficacy, ultimately promoting self-management in women with GDM.[39] Among sources of family support, partners play particularly remarkable roles. Symons et al[40] identified partners as the most impactful figures, influencing exercise behaviors during and after pregnancy in women with GDM. Furthermore, He et al,[41] through a synthesis of 10 studies across 6 countries, confirmed that partner support could positively influence GDM management, and several women reported their partners' role in maintaining healthy diets and participating in PA, such as walking together. Vounzoulaki et al,[42] in a systematic review and meta-analysis, emphasized the high risk of progression to type 2 diabetes following a pregnancy with GDM and underscored the necessity of systematic postpartum screening and long-term follow-up strategies to improve health outcomes. To promote PA in women following low-level stable trajectories, clinicians are advised to implement family-centered intervention models,[13] actively involving family members in exercise planning or participation to strengthen perceived support and improve adherence.[43]

Limitations

This study has several limitations. Firstly, data collection was confined to a single tertiary hospital, and the limited sample size restricted the generalizability of findings. Secondly, the analysis of influencing factors did not encompass all potential variables, such as social and psychological factors, resulting in an incomplete understanding of the determinants underlying PA trajectory subgroups among pregnant women with GDM. Finally, the reliance on subjective PA questionnaires without objective measures, such as pedometers, might introduce reporting bias.

Strengths

This longitudinal study elucidated the PA levels of women with GDM across various gestational weeks and identified population heterogeneity in activity trajectories using LCGM, providing evidence for clinicians to detect interventional targets and develop personalized PA plans for GDM management, ultimately improving clinical outcomes in GDM.

Recommendations for Future Research

Future studies should investigate the patterns of PA in women with GDM in different regions and cultural backgrounds to reliably identify the PA trajectories. One-to-one semi-structured interviews can be conducted with individuals in the low-level stable group to explore their experiences when engaging in PA during this period. It is also necessary to develop targeted PA intervention programs for different subgroups, to provide a reliable reference for clinical practice to improve and stabilize the PA level of pregnant women with GDM and improve their health outcomes.

Conclusions

The PA levels of women with GDM initially increased and subsequently decreased as the gestational weeks progressed. There was heterogeneity in the trajectory of PA levels, and the largest group maintained consistently low activity. Unemployment and exercising alone were found as fundamental factors influencing these PA patterns. Therefore, future studies should develop more effective interventions targeting specific PA trajectories for pregnant women with GDM, with particular emphasis on improving activity levels in the predominant low-level stable subgroup to optimize maternal-fetal health outcomes.

Abbreviations

aBIC, adjusted Bayesian Information Criterion; AIC, Akaike Information Criterion; BIC, Bayesian Information Criterion; BLRT, Bootstrap likelihood ratio test; BMI, Body Mass Index; FBG, Fasting blood glucose; 2h-PG, 2-hour postprandial glucose; GDM, Gestational Diabetes Mellitus; Glut-4, Glucose transporter 4; HMGB1, High Mobility Group Box 1; LMR, Lo-Mendell-Rubin likelihood ratio test; LCGM, Latent Class Growth Model; MET, Metabolic Equivalent of Task; NF-κB, Nuclear Factor-κB; OGTT, Oral Glucose Tolerance Test; OR, Odds Ratio; PA, Physical activity; PPAQ, Pregnancy Physical Activity Questionnaire; RAGE, Receptor for Advanced Glycation Endproducts.

Data Sharing Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Ethics Approval and Informed Consent

Participants provided signed informed consent. The study protocol was approved by the Ethics Committee of Guangdong Women and Children Hospital (Approval number: 202401007). The study complies with the Declaration of Helsinki.

Acknowledgment

We thank Medjaden Inc. for scientific editing of this manuscript.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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