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Association between gestational weight change trajectories and perinatal outcomes in twin pregnancies in China

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Abstract

Objective This study aimed to identify gestational weight change trajectories and examine their association with perinatal outcomes.

Methods Prenatal and delivery records of 3393 twin pregnancies were obtained from the China–US Collaborative Project for Neural Tube Defects Prevention, a large population-based cohort study. Generalized gestational weight gain (GWG) was calculated by dividing the total GWG by the length of gestation in weeks and multiplying by 37 weeks. Latent class growth modeling (LCGM) was used to identify GWG patterns. Multivariable logistic regression and generalized estimating equations (GEE) were used to analyze the associations between GWG trajectories and perinatal outcomes. The included adverse perinatal outcomes were preterm birth, low birth weight (LBW), small for gestational age (SGA), and large for gestational age (LGA).

Results The mean ± SD of GWG for underweight women was 17.87 ± 5.67 kg, 16.76 ± 6.22 kg for normal weight, 14.34 ± 6.60 kg for overweight, and 14.27 ± 4.94 kg for obese. Three gestational weight change trajectory groups were identified: low-increase (32.36%), moderate-increase (56.26%), and high-increase (11.38%). Compared to the moderate-increase group, the high-increase group showed a reduced risk of LBW (aOR 0.68, 95%CI 0.56, 0.83), and SGA (aOR 0.49, 95%CI 0.40, 0.60) but an increased risk of LGA (aOR 2.23, 95%CI 1.48, 3.35). No significant change was observed in the risk of preterm birth in the high-increase group. The low-increase group had a higher risk of preterm birth (aOR 1.66 95%CI 1.42, 1.94), LBW (aOR 2.44 95%CI 2.13,2.80), and SGA (aOR 1.32 95%CI 1.16, 1.51), with no significant difference in the risk of LGA (aOR 1.11 95%CI 0.78,1.58).

Conclusions Distinct patterns of GWG in twin pregnancies are associated with varying risks of adverse perinatal outcomes. These findings highlight the importance of monitoring and managing GWG in twin pregnancies.

Keywords Twin pregnancies, Gestational weight change trajectory, Adverse perinatal outcomes

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Introduction

Twin pregnancies, which account for approximately 1.49% of all births in China, are associated with an increased risk of adverse perinatal outcomes compared to singleton pregnancies [1]. Nearly 58% of twins are born preterm, and their incidence of being small for gestational age (SGA) is significantly higher compared to singletons, with rates of 37.6% versus 7.0%, respectively [2, 3]. At the same time, mothers carrying twins tend to gain more weight compared to those carrying singleton [4].

Maternal pre-pregnancy body mass index (BMI) and gestational weight gain (GWG) are associated with many adverse pregnancy complications [5, 6]. Overweight and obese women are at an increased risk for common pregnancy complications, including hypertensive disorders, preterm birth, and delivering large for gestational age (LGA) infants [7, 8]. GWG also plays a critical role in determining pregnancy outcomes. Higher GWG in both singleton and twin pregnancies is linked to LGA, while insufficient GWG is associated with preterm birth, low birth weight (LBW) and SGA [9, 10]. Although comprehensive guidelines for GWG stratified by pre-pregnancy BMI have been established for singleton pregnancies [4], evidence-based recommendations for twin pregnancies in China is limited. Currently, the recommendations of Institute of Medicine (IOM) represent a widely accepted standard for GWG. However, the IOM has only issued provisional guidelines for twin pregnancies, based on data from a single study, and has not provided recommendations for GWG across all pre-pregnancy BMI categories [4, 11]. The existing IOM suggest a GWG range of 17–25 kg for normal pre-pregnancy BMI, 14–23 kg for overweight, and 11–19 kg for obesity [4].

Previous research mainly focused on the total GWG, assuming that all women follow the same gain pattern [9, 12]. However, there might be subgroups within the population, having different weight gain trajectories. Understanding the relationship between GWG patterns and perinatal outcomes in twin pregnancies is essential for improving pregnancy management and outcomes [13, 14]. While there is extensive data on the relationship between GWG and pregnancy outcomes in singleton pregnancies [15, 16], the impact of GWG on twin pregnancy outcomes remains less consistent [17, 18]. Moreover, with the unprecedented rise of twin pregnancies, there is a growing need to explore how the GWG affects the risk of common pregnancy complications in twin pregnancies.

Therefore, this study aims to comprehensively investigate the intricate associations between gestational weight gain trajectories and adverse perinatal outcomes, with the primary objective of elucidating potential risk factors and providing nuanced insights into maternal-fetal health dynamics.

Methods

Study design and subjects

The data for this study was sourced from a public health campaign conducted in China from 1993 to 1996 (More detailed information about the original design and population has been described previously [19, 20]). The campaign, targeting neural tube defect prevention, provided folic acid supplements and was implemented by the Chinese Ministry of Health across 21 counties in 2 southern provinces (Zhejiang and Jiangsu) and 1 northern province (Hebei). Data were collected using a maternal and child health monitoring system established as part of the public health campaign. This system was designed to record comprehensive perinatal health data and monitor early developmental of children. The monitoring system recorded until 2007, ensuring a large population-based cohort.

The original dataset included records of 15,525 twin pregnancies, allowing for detailed analysis of perinatal outcomes specifically among twin gestations. In this study, 5,534 women with twin pregnancies who enrolled before pregnancy and had the pre-pregnancy weight were selected. Of these women, we excluded 184 (3.32%) with outcomes of selective reduction or stillbirth, 51 (0.92%) with major congenital birth defects, and 1,338 (24.18%) with missing weight and height or abnormal records in the initial phase of selection. Demographic characteristics between the final included participants ($n = 3,393$) and the excluded pregnancies was summarized in Table(S1). In the second phase of selection, 9 women (0.16%) were excluded, with age < 18 or > 45 years; 170 (3.07%) with abnormal infant birth weight; 41(0.74%) with abnormal weight gain (weight gain < 0 or > 40 kg); 339 (6.13%) with the second weight measurement not recorded in the first trimester; and 9 (0.16%) with a gestational age of < 24 weeks or > 42 weeks. After these exclusions, 3,393 eligible participants were included in the study (Fig. 1).

This study has obtained approval from the Biomedical Ethics Committee of Peking University (Ethics Number: IRB00001052-24076).

Gestational weight gain

Height and weight were measured by trained local health workers. Weight (kg) and height (cm) were recorded while participants wore light indoor clothing without shoes, overcoats, or hats. All measuring instruments were calibrated by local quality and technical supervision experts. Pre-pregnancy weight and height were documented during registration used the same method mentioned above. Weight and height at the first prenatal visit,

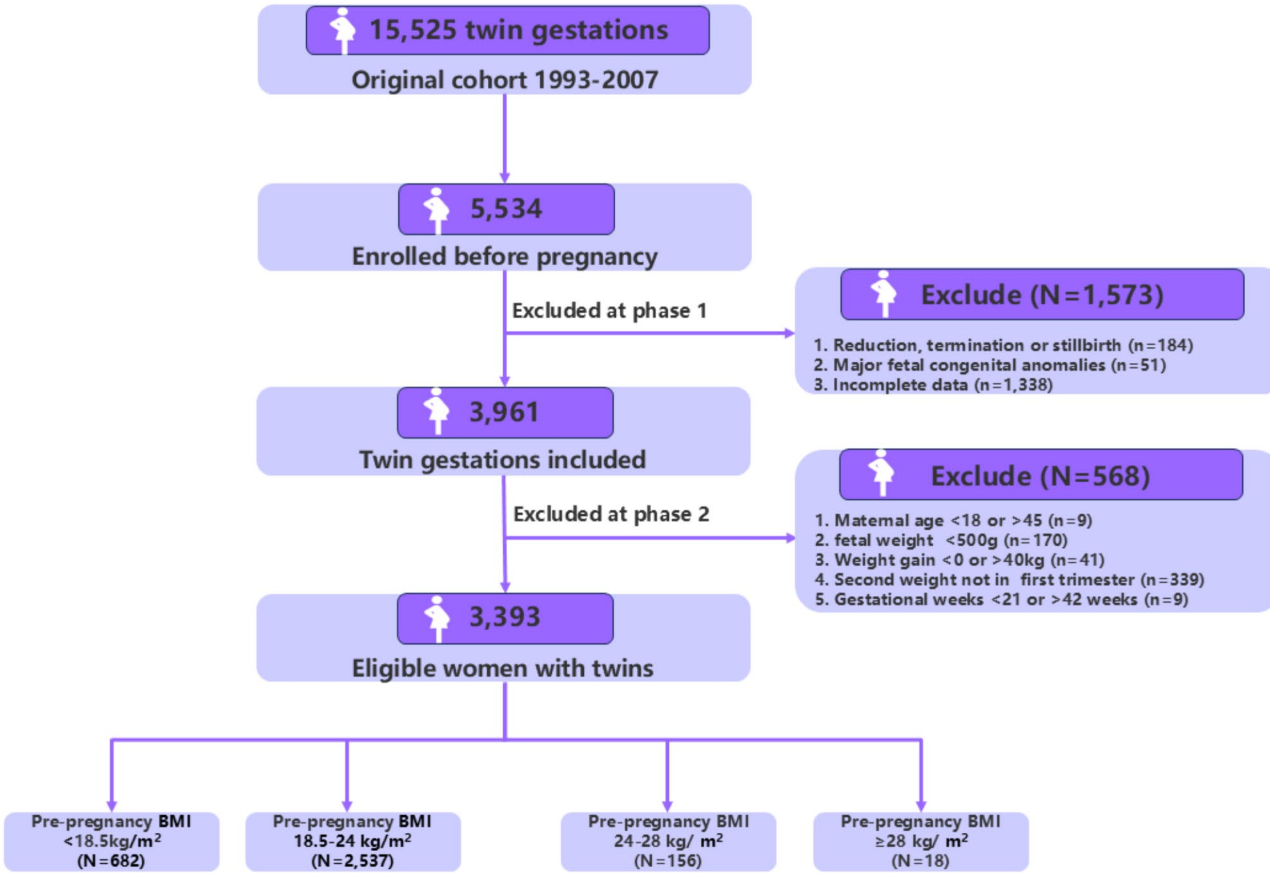

Fig. 1 The flowchart of the enrolled participants

as well as pre-delivery weight were recorded throughout the course of prenatal care. All women in the final analysis had completed weight change data. The gestational weeks were assessed for their distribution. The median gestational week at the first weight measurement was 9 weeks (interquartile range [IQR]: 7–11 weeks), with a mean of 9.01 weeks (standard deviation [SD]: 2.21 weeks). The distribution was symmetric (skewness: -0.20) and exhibited no extreme kurtosis (kurtosis: 2.34). Additionally, 90% of the measurements were taken between 6 and 12 weeks of gestation. These results indicate that the first weight measurement was sufficiently concentrated within early pregnancy to be treated as a single time point in the analysis. Gestational age was calculated based on the woman's last normal menstrual period. Total GWG was calculated by subtracting pre-pregnancy weight from the pre-delivery weight. In the current study, the main exposure variable was the standardized GWG equivalent to 37 weeks of gestation, which was calculated by dividing the total GWG by the length of gestation in weeks and multiplying by 37 weeks [21, 22].

Perinatal outcomes

We collected detailed maternal and neonatal data, including maternal height, weight, gestational age at delivery, infant sex, and birth weight. Adverse perinatal outcomes assessed in the study included preterm birth, low birth weight (LBW), small for gestational age (SGA) and large for gestational age (LGA). Preterm birth was defined as delivery before 37 weeks of twin gestation and was further categorized into two clinical subtypes: spontaneous and medically indicated subtypes. Low birth weight was defined as birth weight < 2500 g. SGA (birthweights below the 10th centile for gestational age) and LGA (birthweights greater than the 90th centile for gestational age) were defined according to Chinese standard [23]. At the time of the analysis, there were no widely available, validated twin-specific birthweight percentiles for the Chinese population. Therefore, the definition for SGA and LGA were based on singleton pregnancy. A composite outcome was also defined as the occurrence of any of the following: preterm birth, LBW, SGA, or LGA.

Covariate assessment

Maternal characteristics, including age, occupation, ethnicity, education level, region and gravid were collected from the maternal and child health monitoring system described above. Pre-pregnancy BMI was calculated as dividing pre-pregnancy weight (kg) by the square of height (m^2). Pre-pregnancy BMI was categorized into four groups: underweight (< 18.5 kg/m^2), normal weight (18.5–24 kg/m^2), overweight (24–28 kg/m^2) and obese (≥ 28 kg/m^2) using the Chinese criteria [24].

Statistics

Descriptive statistics were used to summarize the baseline characteristics of the study population. Continuous variables are presented as means ± standard deviations (SDs), while categorical variables are expressed as ratios (percentages). Between-group comparisons for categorical variables were conducted using the Chi-square test, while continuous variables were compared using the t-test or the Mann-Whitney U test.

Latent class growth model (LCGM) was performed using Stata Plugin "traj" to identify the gestational weight change trajectory patterns [25]. LCGM operates on the assumption that a population consists of distinct groups, each characterized by unique patterns or trajectories over time. It further assumes that individuals within each group follow a consistent trajectory [26]. Trajectory model was determined based on the Bayesian information criterion (BIC), with a lower value indicating better model performance. An average posterior probability of 0.70 or higher for each group is considered as good discrimination in classifying individuals into distinctive groups. The three-class trajectory model was determined and the trajectories of each group were fitted with a polynomial of the highest order of 3, with the smallest group ratio no less than 5% (Table S2). Although Class 2 showed the lowest BIC value, we opted for the three-class model because it provided a more meaningful and clinically relevant distinction between groups. This classification aligns with practical prenatal care experience, where GWG is often categorized into three distinct groups: excessive, insufficient, and adequate. In addition, the three-class model offered better group separation, as indicated by the higher entropy (0.792 vs. 0.740), which may provide a more nuanced and accurate representation of the data. Three trajectory groups were identified and named as low-increase group, moderate-increase group and high-increase group (Table S3).

A multivariable logistic regression was used to analyze the association between gestational weight change trajectory groups and preterm birth, presenting both unadjusted and adjusted results. A generalized estimating equation (GEE) model with a binomial family and a logit link was performed to analyze the association between gestational weight change trajectory groups and perinatal outcomes (LBW, SGA or LGA), controlling for the clustering of twins within a pair. In this analysis, Level 1 represents individual fetuses (first or second in a twin pair), and Level 2 represents the twin pair as the clustering unit. Maternal age, BMI, ethnicity, occupation, education level, gravidity, place of origin and twin gender were adjusted as covariates.

Level 1 (Fetal level): $g(\pi ij) = \beta_0 j + \beta_8(\text{Twin Gender}ij)$.

Level 2 (Twin pair level): $\beta_0 j = \gamma_{00} + \gamma_1(\text{Age}j) + \gamma_2(\text{BMI}j) + \gamma_3(\text{Ethnicity}j) + \gamma_4(\text{Occupation}j) + \gamma_5(\text{Education}j) + \gamma_6(\text{Gravidity}j) + \gamma_7(\text{Province}j) + u_0 j$.

Combined full model: $g(\pi ij) = \gamma_{00} + \gamma_1(\text{Age}j) + \gamma_2(\text{BMI}j) + \gamma_3(\text{Ethnicity}j) + \gamma_4(\text{Occupation}j) + \gamma_5(\text{Education}j) + \gamma_6(\text{Gravidity}j) + \gamma_7(\text{Province}j) + \beta_8(\text{Twin Gender}ij) + u_0 j$

Where:

i denotes the individual fetus (Level 1).

j denotes the twin pair (Level 2).

$g(\cdot)$ is the logit link function.

$u_0 j$ is the random effect at twin pair level, and $u_0 j \sim N(0, \tau^2{}_0)$.

The optimal GWG ranges for twin pregnancies, stratified by BMI category, were calculated as the interquartile range (IQR) of total GWG within the group without any composite outcome.

All statistical analyses were performed using Stata, version 18.0 (StataCorp). Statistical significance was defined as a two-tailed p-value < 0.05.

Results

Study population characteristics and optimal GWG

A total of 3,393 women with twin gestations were included in the study. The participants were categorized into four groups based on pre-pregnancy BMI: underweight 682 (20.10%), normal weight 2,537 (74.77%), overweight 156 (4.60%), and obese 18 (0.53%), with a mean (SD) age of 24.63 ± 2.43, 24.53 ± 2.61, 24.78 ± 3.15, and 25.50 ± 3.38 years, respectively. Population characteristics are outlined in Table 1. Mean birth weight was lowest in the underweight group (2,349.07 ± 519.76 g) and highest in the obese group (2,709.72 ± 824.69 g). The incidence of preterm birth was highest in the underweight group (44.13%) and lowest in the overweight group (34.62%). LBW and SGA rates were highest in the underweight group (56.67% and 42.74%, respectively), while LGA incidence was greatest among the obese (11.11%), indicating BMI-related differences in birth outcomes. As shown in Table 1, significant differences were observed among the groups regarding the impact of pre-pregnancy BMI on adverse perinatal outcomes, including preterm birth ($p = 0.020$), LBW ($p < 0.001$), SGA ($p = 0.011$) and LGA ($p = 0.034$).

The mean GWG varied across BMI categories, with higher weight gain observed in lower pre-pregnancy BMI categories (Table 1). GWG was 17.87 ± 5.67 kg in the underweight group, similar at 16.76 ± 6.22 kg in the normal weight group, but decreased in the overweight

Table 1 Maternal and neonatal characteristics by pre-pregnancy BMI category in twin pregnancies

Variables, *n*(%) or mean (± SD)	Pre-pregnancy BMI < 18.5 kg/m^2	Pre-pregnancy BMI 18.5–24 kg/m^2	Pre-pregnancy BMI 24–28 kg/m^2	Pre-pregnancy BMI ≥ 28 kg/m^2	*P* value
n	682 (20.10)	2,537 (74.77)	156 (4.60)	18 (0.53)	
Age, y	24.63 ± 2.43	24.53 ± 2.61	24.78 ± 3.15	25.50 ± 3.38	0.029
Age group (y)					0.009
< 25	365 (53.52)	1,456 (57.39)	91 (58.33)	10 (55.56)	
25–30	291 (42.67)	951 (37.49)	52 (33.33)	5 (27.78)	
≥ 30	26 (3.81)	130 (5.12)	13 (8.33)	3 (16.67)	
Gravid					0.048
1	343 (50.29)	1,322 (52.11)	76 (48.72)	8 (44.44)	
2	246 (36.07)	871 (34.33)	58 (37.18)	8 (44.44)	
3	77 (11.29)	273 (10.76)	12 (7.69)	0 (0.00)	
≥ 4	16 (2.35)	71 (2.80)	10 (6.41)	2 (11.11)	
Han ethnicity	679 (99.56)	2,522 (99.41)	154 (98.72)	18 (100.00)	0.975
Place of Origin					< 0.001
Southern Province	654 (95.89)	2,271 (89.52)	133 (85.26)	11 (61.11)	
Northern Province	28 (4.11)	266 (10.48)	23 (14.74)	7 (38.89)	
Education level					< 0.001
Junior high school/below	426 (62.46)	1,799 (70.91)	135 (86.54)	15 (83.33)	
High school	193 (28.30)	559 (22.03)	19 (12.18)	3 (16.67)	
College or above	63 (9.24)	179 (7.06)	2 (1.28)	0 (0.00)	
Occupation					< 0.001
Farmer	282 (41.35)	1,214 (47.85)	102 (65.38)	11 (61.11)	
Factory worker	268 (39.30)	965 (38.04)	47 (30.13)	6 (33.33)	
Service and Business Personnel	84 (12.32)	244 (9.62)	5 (3.21)	0 (0.00)	
Others	48 (7.04)	114 (4.49)	2 (1.28)	1 (5.56)	
Total GWG, kg	17.87 ± 5.67	16.76 ± 6.22	14.34 ± 6.60	14.27 ± 4.94	0.002
Adherence to IOM					0.565
Insufficient	--	1,334 (52.58)	80 (51.28)	6 (33.33)	
Adequate	--	957 (37.72)	60 (38.46)	9 (50.00)	
Excessive	--	246 (9.70)	16 (10.26)	3 (16.67)	
Infant sex					0.823
Male/Male	288 (42.23)	1,029 (40.56)	68 (43.59)	9 (50.00)	
Female/Female	260 (38.12)	1,033 (40.72)	60 (38.46)	7 (38.89)	
Female/Male	134 (19.65)	475 (18.72)	28 (17.95)	2 (11.11)	
Preterm birth	301 (44.13)	964 (38.00)	54 (34.62)	7 (38.89)	0.020
Birth weight, g [a]	2349.07 ± 519.76	2441.05 ± 499.14	2530.11 ± 525.52	2709.72 ± 824.69	< 0.001
LBW [a]	773/1,364 (56.67)	2,507/5,074 (49.41)	124/312 (39.74)	16/36 (44.44)	< 0.001

Table 1 (continued)

Variables, *n*(%) or mean (±SD)	Pre-pregnancy BMI < 18.5 kg/m^2	Pre-pregnancy BMI 18.5–24 kg/m^2	Pre-pregnancy BMI 24–28 kg/m^2	Pre-pregnancy BMI ≥ 28 kg/m^2	*P* value
SGA [a]	583/1,364 (42.74)	1,952/5,074 (38.47)	109/312 (34.94)	12/36 (33.33)	0.011
LGA [a]	40/1,364 (2.93)	203/5,074 (4.00)	13/312 (4.17)	4/36 (11.11)	0.034

SD, standard deviation; BMI, body mass index; GWG, gestational weight gain; IOM, US Institute of Medicine; LBW, low birth weight; SGA, small for gestational age; LGA, large for gestational

[a] data collected at the newborn level

and obesity groups, at 14.34 ± 6.60 kg and 14.27 ± 4.94 kg, respectively. In the normal weight group, 52.58% (1,334/2,537) of individuals gained weight below the IOM guidelines, compared to 51.28% (80/156) in the overweight group and 33.33% (6/18)in the obese group, while 9.70% (246/2,537)of individuals in the normal weight group above the IOM guidelines, a proportion that increased to 16.67% (3/18)in the obese group.

A total of 1,277 individuals with a normal composite outcome were categorized as the low-risk group, comprising 206 underweight, 999 normal weight, 66 overweight, and 6 obese individuals. The optimal GWG ranges after 37 weeks of gestation obtained by the IQR of total GWG were 16.4–24.1 kg for underweight, 14.5–22.0 kg for normal weight, 10.0–19.3 kg for overweight. The obese group is too small to determine the optimal GWG range. The optimal ranges in this study for all BMI categories were below the IOM recommendation (Table 2).

Gestational weight trajectory

Using the LCGM method, three gestational weight change trajectory groups were identified: the low-increase group, comprising 32.36% of participants; the moderate-increase group, comprising 56.26%; and the high-increase group, comprising 11.38% (Fig. 2). The moderate-increase trajectory group represented the largest group (n = 1,909), with the majority having a normal pre-pregnancy BMI (73.97%) and the highest proportion meeting the IOM recommendations (n = 961, 50.34%) (Table 3). The high-increase trajectory group had the largest proportion (60.62%) exceeding the IOM guidelines, while the low-increase group had the largest proportion (84.34%) falling below the IOM guidelines (Table 3). In the low-increase and moderate-increase groups, a higher proportion of individuals meet the adequate weight gain in the IQR range compared to the IOM recommendation (Table 3). The low-increase group had the highest incidence of spontaneous preterm birth, LBW, and SGA, whereas LGA were most prevalent in the high-increase group (Table S4).

Total GWG showed wide variation within each pre-pregnancy BMI category and across different trajectory groups (Fig. 3). In the normal weight-low-increase group, 99.88% participants fell below the IOM recommendations. As pre-pregnancy BMI increased, the proportion falling below the IOM recommendations decreased, from 98.68% in the overweight-low-increase group to 85.71% in the obese-low-increase group. In the moderate-increase group with different pre-pregnancy BMIs, the proportion meeting the IOM recommendations was the highest. A gain over the upper limit was observed in 210 (75.27%) and 14 (87.50%) participants in the normal weight and overweight high-increase group, respectively.

Table 2 Comparison of GWG IQR with IOM recommendations

BMI Category	IQR	IOM recommendations
Underweight (BMI < 18.5 kg/m^2)	16.4–24.1	ND
Normal weight (BMI 18.5–24 kg/m^2)	14.5–22.0	17–25
Overweight (BMI 24–28 kg/m^2)	10.0-19.3	14–23
Obese (BMI ≥ 28 kg/m^2)	ND	11–19

Abbreviations: BMI, body mass index; GWG, gestational weight gain; IQR, Interquartile range; IOM, US Institute of Medicine; ND: not determined

The three trajectory groups exhibited small variations during the first trimester. The low-increase group experienced a slight weight loss, the moderate-increase group showed almost no change between pre-pregnancy and first-trimester weight, while the high-increase group had an average weight gain of 4.76 kg during this period.

Association between gestational weight change trajectories and adverse perinatal outcomes

Compared to the moderate-increase group (reference), the high-increase group showed a reduced risk of LBW, and SGA, but an increased risk of LGA (Table 4). The risk of preterm birth was not associated with the high-increase group. The low-increase group showed an increased risk of preterm birth, LBW, and SGA, compared to the reference moderate-increase group, with no difference in the risk of LGA. After excluding pre-pregnancy BMI as a covariate, the odds ratios (ORs) for several outcomes showed slight changes but the overall associations remained unchanged (Table S5).

Subgroup analysis by BMI category regarding the relationship of GWG trajectories and perinatal outcomes was performed. Compared to the moderate-increase group, the low-increase group showed higher risks for preterm birth and LBW across both underweight and normal weight categories. In the high-increase group, a reduced risk of preterm birth, LBW and SGA was observed in underweight women, while a reduced risk of LBW and SGA was observed in the normal weight women (Table S6).

Discussion

Using longitudinal data from a large cohort in China from 1993 to 2007, we identified three distinct patterns of GWG and analyzed their associations with adverse

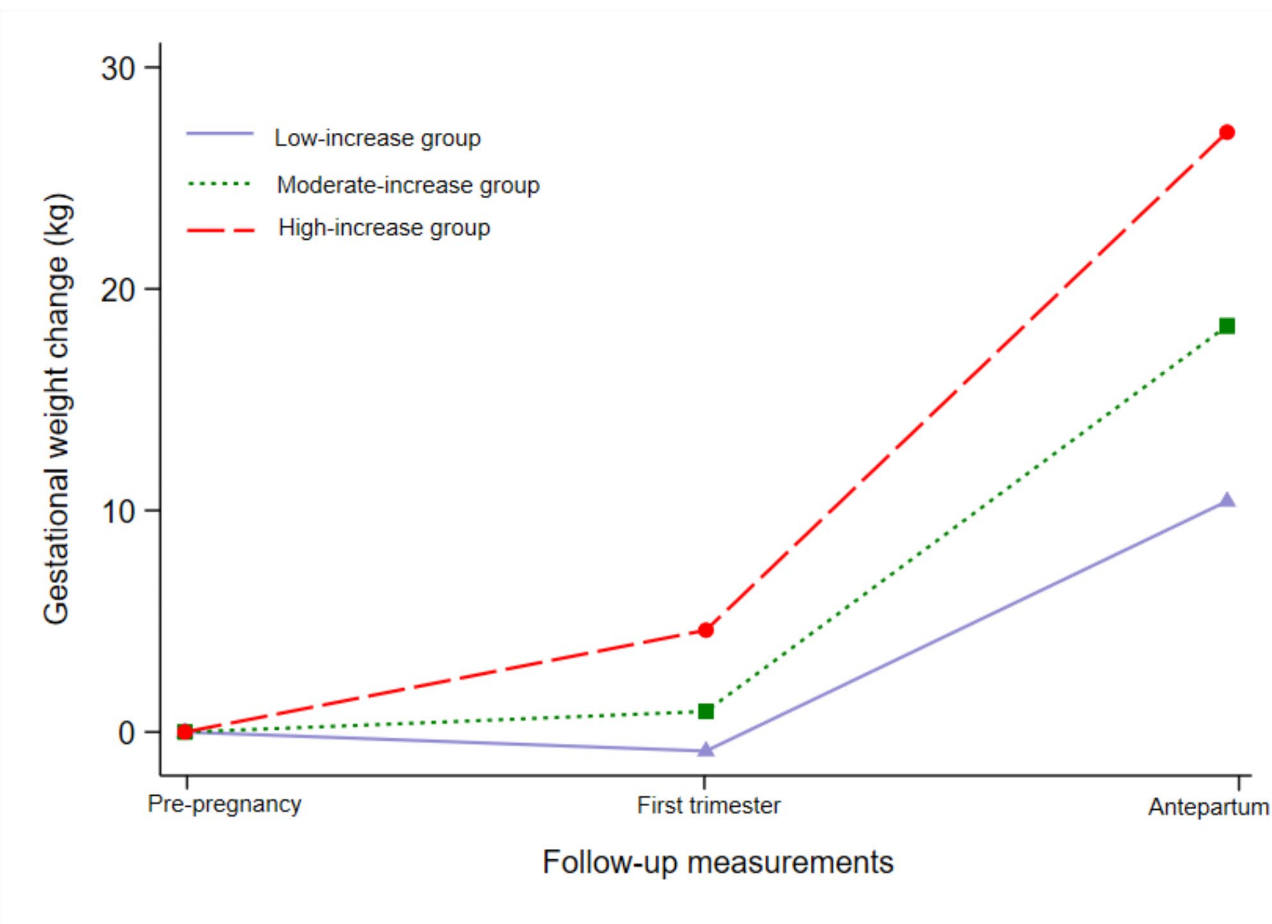

Fig. 2 Gestational weight change trajectory groups of the study participants

Table 3 Basic information of participants based on gestational weight change trajectory groups

Variables, *n*(%) or mean (± SD)	Low-increase group (*n* = 1,098)	Moderate-increase group (*n* = 1,909)	High-increase group (*n* = 386)	*p* value
Maternal characteristics				
Age, y	24.27 ± 2.56	24.61 ± 2.61	25.17 ± 2.65	< 0.001
Age group (y)				< 0.001
< 25	694 (63.21)	1,055 (55.26)	173 (44.82)	
25–29	352 (32.06)	757 (39.65)	190 (49.22)	
>=30	52 (4.74)	97 (5.08)	23 (5.96)	
Pre-pregnancy BMI				< 0.001
< 18.5 kg/m^2	169 (15.39)	423 (22.16)	90 (23.32)	
18.5–24 kg/m^2	846 (77.05)	1,412 (73.97)	279 (72.28)	
24–28 kg/m^2	76 (6.92)	64 (3.35)	16 (4.15)	
≥ 28 kg/m^2	7 (0.64)	10 (0.52)	1 (0.26)	
Han ethnicity	1,094 (99.64)	1,897 (99.37)	382 (98.96)	0.370
Place of Origin				< 0.001
Southern Province	999 (90.98)	1,749 (91.62)	321 (83.16)	
Northern Province	99 (9.02)	160 (8.38)	65 (16.84)	
Education level				< 0.001
Junior high school/below	873 (79.51)	1,285 (67.31)	217 (56.22)	
High school	174 (15.85)	477 (24.99)	123 (31.87)	
College or above	51 (4.64)	147 (7.70)	46 (11.92)	
Occupation				< 0.001
Farmer	626 (57.01)	844 (44.21)	139 (36.01)	
Factory worker	376 (34.24)	751 (39.34)	159 (41.19)	
Service and Business Personnel	60 (5.46)	217 (11.37)	56 (14.51)	
Others	36 (3.28)	97 (5.08)	32 (8.29)	
Gravid	1.58 ± 0.79	1.68 ± 0.83	1.75 ± 0.86	< 0.001
Total GWG, kg	10.34 ±3.05	18.45 ± 3.05	27.55 ± 3.75	< 0.001
Adherence to IOM				< 0.001
Insufficient	926 (84.34)	494 (25.88)	0 (0.00)	
Adequate	3 (0.27)	961 (50.34)	62 (16.06)	
Excessive	0 (0.00)	31 (1.62)	234 (60.62)	
Adherence to IQR				< 0.001
Insufficient	1,020(92.90%)	226(11.84%)	0(0.00%)	
Adequate	71(6.47%)	1,442(75.54%)	31(8.03%)	
Excessive	0(0.00%)	52(2.72%)	255(66.06%)	
Neonatal characteristics				
Infant sex				0.095
Male/Male	439 (39.98)	798 (41.80)	157 (40.67)	
Female/Female	461 (41.99)	760 (39.81)	139 (36.01)	
Female/Male	198 (18.03)	351 (18.39)	90 (23.32)	
Delivery gestational age(weeks)	36.1 ± 2.74	36.9 ± 2.19	36.8 ± 2.00	< 0.001
Birth weight, g[a]	2247.06 ± 518.40	2488.27 ± 469.44	2645.35 ± 514.36	< 0.001

SD, standard deviation; BMI, body mass index; GWG, gestational weight gain; IOM, US Institute of Medicine

[a] data collected at the newborn level

perinatal outcomes including preterm birth, LBW, SGA and LGA. Our result indicated that the risk of adverse perinatal outcomes varies by GWG patterns. The optimal GWG in this study was below the IOM recommendations across all BMI categories, with ranges of 16.4–24.1 kg for underweight, 14.5–22.0 kg for normal weight, and 10.0–19.3 kg for overweight.

This study utilized data from 1993 to 2007, a period when living conditions, healthcare systems, and societal norms in China were markedly different from today [27]. At that time, nutritional awareness and prenatal care services were less developed, leading to distinct pregnancy outcomes compared to current cohorts [28]. These historical factors likely influenced the GWG

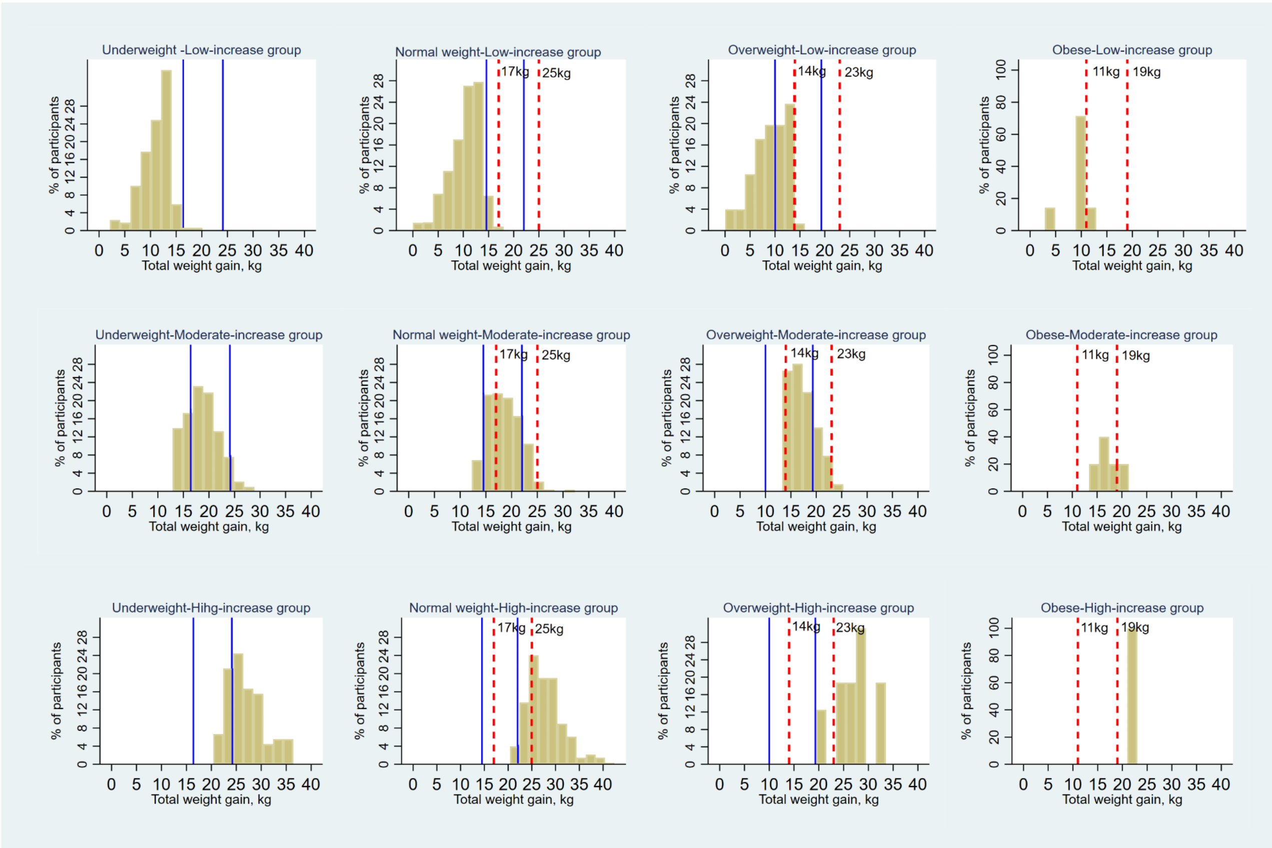

Fig. 3 Total gestational weight gain by pre-pregnancy BMI category among participants. Total weight gain is shown in 2 kg blocks. The red dash line indicates the lower and upper limits for total gestational weight gain in twins according to IOM guidelines. The blue line indicates the lower and upper limits according to IQR

Table 4 The associations of gestational weight change trajectory groups with the incidence of adverse perinatal outcomes in twin pregnancies

Trajectory groups	**Preterm birth**		**LBW[a]**		**SGA[a]**		**LGA[a]**	
	Un-adjusted OR(95% CI)	**Adjusted OR (95% CI)**	**Un-adjusted OR(95% CI)**	**Adjusted OR(95% CI)**	**Un-adjusted OR(95% CI)**	**Adjusted OR (95% CI)**	**Un-adjusted OR(95% CI)**	**Adjusted OR (95% CI)**
Moderate-increase group (*n* = 1,909)	Reference	Reference	Reference	Reference	Reference	Reference	Reference	Reference
Low-increase group (*n* = 1,098)	1.59(1.37–1.85)	1.66 (1.42–1.94)	2.32 (2.04–2.65)	2.44 (2.13–2.80)	1.35 (1.19–1.53)	1.32 (1.16–1.51)	1.13 (0.80–1.60)	1.11 (0.78–1.58)
High-increase (*n* = 386)	0.95(0.76–1.20)	1.00 (0.79–1.26)	0.63 (0.52–0.76)	0.68 (0.56–0.83)	0.49 (0.40–0.60)	0.49 (0.40–0.60)	2.51 (1.69–3.72)	2.23 (1.48–3.35)

OR, odds ratio; CI, confidence interval; LBW, low birth weight; SGA, small for gestational age; LGA, large for gestational age

[a] data collected at the newborn level

The analysis for preterm birth was performed using multivariable logistic regression. Adjusted for maternal age (continuous), BMI (continuous), ethnicity, place of Origin, education, occupation, gravid, twin gender

The analyses for LBW, SGA, and LGA were performed using Generalized Estimating Equations (GEE) with a binomial family and logit link, adjusted for maternal age (continuous), BMI (continuous), ethnicity, place of origin, education, occupation, gravidity, and twin gender

patterns observed in our study. For example, the prevalence of overweight and obesity was considerably lower during the study period due to the country's earlier economic stage. This contrasts with recent years, where higher obesity rates and altered dietary patterns have shifted GWG trends [29]. In this study, the GWG of most cases was lower than IOM recommendations. However, this study provides important GWG references for underweight pregnant women, particularly in cases where existing guidelines may not fully apply to certain subgroups.

Three distinct gestational weight change trajectory groups were identified: low-increase (average GWG of 10.34 kg), moderate-increase (average GWG of 18.45 kg), and high-increase (average GWG of 27.55 kg). Women who exceeded the IOM recommendations were more likely to belong to the high-increase group, whereas those with a pre-pregnancy BMI classified as overweight or obese were more likely to fall into the low-increase group, similar to previous finding in singleton pregnancy [30]. Our findings suggest that the low-increase trajectory was associated with a higher risk of preterm birth, LBW, and SGA, while the high-increase trajectory was linked to an increased risk of LGA, but a reduced risk of LBW, and SGA. These results align with previous studies on twin pregnancies, which have shown that excessive GWG is associated with an increased risk of LGA and reduced risk of SGA [18, 31, 32]. However, the inverse association of GWG with SGA is inconsistent with several twin studies [17, 33]. It is difficult to compare our findings to these twin studies considering we focused on gestational weight change trajectories. Besides, we used the standardized GWG to minimize the effect of gestational weeks, considering many studies only use the total GWG as variable.

Emerging evidence suggests that weight change in the first trimester may play a significant role in fetal development and the long-term health of the child [34, 35]. Weight gain during the first trimester is generally minimal in singleton pregnancies, typically ranging from 0.5 to 2 kg across all BMI categories recommended by the IOM [4]. However, our study observed distinct patterns of gestational weight change during this period. In our study, the low-increase group experienced slight weight loss during the first trimester, the moderate-increase group showed little difference between pre-pregnancy weight and first-trimester weight, while the high-increase group had an average weight gain of 4.76 kg during this period. Many studies rely on self-reported pre-pregnancy weight when early first-trimester weight measurements are unavailable, often disregarding the significance of weight gain during this critical period [36]. Nichols et al. has reported three distinct GWG trajectories in twin pregnancies with similar GWG at 10 weeks of gestation [37]. However, their study did not specifically address the role of weight gain during the first trimester. Ashtree et al. investigated GWG trajectories and focused on patterns occurring after the first trimester [38].

Pre-pregnancy BMI is a known factor influencing both GWG and pregnancy outcomes [39–41]. In our study, women in the underweight group had the highest incidence of preterm birth, LBW, and SGA, while those in the obese group had the highest incidence of LGA. A meta-analysis highlighted that pre-pregnancy BMI has a stronger association with adverse pregnancy complications compared to GWG in singleton pregnancy [16]. In our study, the incidence of LBW, SGA, and LGA varied significantly across BMI range. Consistent with the IOM guidelines [4], this study showed that women with highest pre-pregnancy BMI had the lowest GWG. For underweight women, they were likely falling below the IOM recommendations, while women in the obese group were more likely to exceed the IOM recommendations. Adherence to the IOM recommendations for GWG is low, with approximately 36.22% (982/2711) of women meeting the guidelines in our study. Previous studies have reported that only about 40% of women with singleton pregnancies in China achieve adequate GWG as recommended by the IOM [42, 43]. The IQR of total GWG in this study was below the IOM recommendations across BMI categories. These findings suggest that the IOM recommendations may not be fully suitable for the Chinese population.

Our study has several strengths. The data were derived from a large population-based study, with systematically recorded exposures and outcomes, ensuring comprehensive data collection and minimizing the risk of selection bias. The study population predominantly consisted of women of Han ethnicity, providing a genetically homogeneous background that helped to minimize residual confounding. An advanced method, LCGM was used to identify GWG patterns and its associations with perinatal outcomes. The LCGM method advanced the research on GWG in this population, by uncovering distinct subgroups with unique weight gain trajectories, providing a deeper understanding of the variability in GWG patterns. We had sufficient data to provide the optimal GWG for the underweight and normal weight women considering our population characteristics.

Limitations

This study had some limitations to consider. First, the data used in this study were collected between 1993 and 2007 in China, which may limit the generalizability of the findings to more recent cohorts. Second, the data only documented three weight measurements: pre-pregnancy, first trimester, and weight before delivery. Additional data from the second and third trimesters would provide more comprehensive insights. Moreover, the missing weight and height or abnormal records in the initial phase of selection is high as the study required at least three- time measurements. This requirement may have introduced selection bias. Then, using standardized GWG and assuming linear weight gain throughout pregnancy may also introduce bias, as GWG is slower in the first and late third trimesters. Lastly, the database lacked the information on chorionicity. In the absence of this data, we used neonatal sex combination as a proxy for chorionicity, which is considered suboptimal in such study [44].

Conclusion

This study identified distinct gestational weight change trajectories in twin pregnancies and their associations with adverse perinatal outcomes. The findings suggest that the low-increase group was associated with a higher risk of preterm birth, LBW, and SGA, while the high-increase group was linked to a higher risk of LGA but a reduced risk of LBW, and SGA.

Abbreviations

LCGM	Latent class growth modeling
GWG	Gestational weight gain
GEE	Generalized estimating equations
LBW	Low birth weight
SGA	Small for gestational age
LGA	Large for gestational age
BMI	Body mass index
IOM	Institute of Medicine
BIC	Bayesian information criterion
IQR	Interquartile range

Supplementary Information

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Supplementary Material 1

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Author contributions

Conceptualization: TH, ZL. Data curation: ML, WD, XT. Formal analysis: ML. Funding acquisition: ZL. Investigation: TH, ZL. Methodology: TW, YZ, WG. Writing—original draft: ML. Writing—review and editing: TH, ZL. All authors read and approved the final manuscript.

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Data availability

Datasets in this study are available from the corresponding author, upon reasonable requests.

Declarations

Ethics approval and consent to participate

This study was approved by the Biomedical Ethics Committee of Peking University (Ethics Number: IRB00001052-24076) and fulfils the ethical principles of the Declaration of Helsinki. All the participants provided written informed consent.

Consent for publication

All the participants consent for the publication.

Competing interests

The authors declare no competing interests.

Conflict of interest

All authors approved the final manuscript and declared no competing interests.

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References

1. Commission NH, Analysis of the Report on Medical Service and Quality Safety of Obstetrics in China. (2023 Edition) [EB/OL]. (2024-01-31). https://www.obqcc.org.cn/#/testing? id = 2c91 8082859 5dcc30187fee5d8ad0008&articleId = 56f1100406774d8daa4048f4fa1f097d.
2. Chauhan SP, Scardo JA, Hayes E, Abuhamad AZ, Berghella V. Twins: prevalence, problems, and preterm births. Am J Obstet Gynecol. 2010;203:305–15.
3. Wright D, Wright A, Rehal A, Syngelaki A, Kristensen SE, Petersen OB, et al. Incidence of neonatal morbidity in small-for-gestational-age twins based on Singleton and twin charts. Ultrasound Obstet Gynecol. 2024;63:365–70.
4. Rasmussen KM, Yaktine AL, editors. Weight Gain During Pregnancy: Reexamining the Guidelines. Washington (DC)2009.
5. Poston L, Caleyachetty R, Cnattingius S, Corvalan C, Uauy R, Herring S, et al. Preconceptional and maternal obesity: epidemiology and health consequences. Lancet Diabetes Endocrinol. 2016;4:1025–36.
6. Santos S, Voerman E, Amiano P, Barros H, Beilin LJ, Bergstrom A, et al. Impact of maternal body mass index and gestational weight gain on pregnancy complications: an individual participant data meta-analysis of European, North American and Australian cohorts. BJOG. 2019;126:984–95.
7. Cnattingius S, Villamor E, Johansson S, Edstedt Bonamy AK, Persson M, Wikstrom AK, et al. Maternal obesity and risk of preterm delivery. JAMA. 2013;309:2362–70.
8. Marchi J, Berg M, Dencker A, Olander EK, Begley C. Risks associated with obesity in pregnancy, for the mother and baby: a systematic review of reviews. Obes Rev. 2015;16:621–38.
9. Goldstein RF, Abell SK, Ranasinha S, Misso M, Boyle JA, Black MH, et al. Association of gestational weight gain with maternal and infant outcomes: A systematic review and Meta-analysis. JAMA. 2017;317:2207–25.
10. Lipworth H, Barrett J, Murphy KE, Redelmeier D, Melamed N. Gestational weight gain in twin gestations and pregnancy outcomes: a systematic review and meta-analysis. BJOG. 2022;129:868–79.
11. Luke B, Hediger ML, Nugent C, Newman RB, Mauldin JG, Witter FR, et al. Body mass index–specific weight gains associated with optimal birth weights in twin pregnancies. J Reprod Med. 2003;48:217–24.
12. Han Z, Lutsiv O, Mulla S, Rosen A, Beyene J, McDonald SD, et al. Low gestational weight gain and the risk of preterm birth and low birthweight: a systematic review and meta-analyses. Acta Obstet Gynecol Scand. 2011;90:935–54.
13. Whitaker KM, Ryan R, Becker C, Healy H. Gestational weight gain in twin pregnancies and maternal and child health: an updated systematic review. J Womens Health (Larchmt). 2022;31:362–81.
14. Bodnar LM, Pugh SJ, Abrams B, Himes KP, Hutcheon JA. Gestational weight gain in twin pregnancies and maternal and child health: a systematic review. J Perinatol. 2014;34:252–63.
15. Goldstein RF, Abell SK, Ranasinha S, Misso ML, Boyle JA, Harrison CL, et al. Gestational weight gain across continents and ethnicity: systematic review and meta-analysis of maternal and infant outcomes in more than one million women. BMC Med. 2018;16:153.

16. LifeCycle Project-Maternal O, Childhood Outcomes Study G, Voerman E, Santos S, Inskip H, Amiano P, et al. Association of gestational weight gain with adverse maternal and infant outcomes. JAMA. 2019;321:1702–15.
17. Fox NS, Saltzman DH, Kurtz H, Rebarber A. Excessive weight gain in term twin pregnancies: examining the 2009 Institute of medicine definitions. Obstet Gynecol. 2011;118:1000–4.
18. Bodnar LM, Himes KP, Abrams B, Lash TL, Parisi SM, Eckhardt CL, et al. Gestational weight gain and adverse birth outcomes in twin pregnancies. Obstet Gynecol. 2019;134:1075–86.
19. Berry RJ, Li Z, Erickson JD, Li S, Moore CA, Wang H, et al. Prevention of neural-tube defects with folic acid in China. China-U.S. Collaborative project for neural tube defect prevention. N Engl J Med. 1999;341:1485–90.
20. Gindler J, Li Z, Berry RJ, Zheng J, Correa A, Sun X, et al. Folic acid supplements during pregnancy and risk of miscarriage. Lancet. 2001;358:796–800.
21. Wang L, Zhang X, Chen T, Tao J, Gao Y, Cai L, et al. Association of gestational weight gain with infant morbidity and mortality in the united States. JAMA Netw Open. 2021;4:e2141498.
22. Lin D, Huang X, Fan D, Chen G, Li P, Rao J, et al. Association of optimal gestational weight gain ranges with perinatal outcomes across body mass index categories in twin pregnancies. JAMA Netw Open. 2022;5:e2222537.
23. Capital Institute of P, Coordinating Study Group of Nine Cities on the Physical G. Development of C. [Growth standard curves of birth weight, length and head circumference of Chinese newborns of different gestation]. Zhonghua Er Ke Za Zhi. 2020;58:738–46.
24. Zhou B, Coorperative Meta-Analysis Group Of Working Group On Obesity In C. [Prospective study for cut-off points of body mass index in Chinese adults]. Zhonghua Liu Xing Bing Xue Za Zhi. 2002;23:431–4.
25. Andruff H, Carraro N, Thompson A, Gaudreau P, Louvet B. Latent class growth modelling: A tutorial. Tutorials Quant Methods Psychol. 2009;5:11–24.
26. Nguena Nguefack HL, Page MG, Katz J, Choiniere M, Vanasse A, Dorais M, et al. Trajectory modelling techniques useful to epidemiological research: A comparative narrative review of approaches. Clin Epidemiol. 2020;12:1205–22.
27. Zhou M, Wang H, Zeng X, Yin P, Zhu J, Chen W, et al. Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: a systematic analysis for the global burden of disease study 2017. Lancet. 2019;394:1145–58.
28. Chen Y, Wu L, Zou L, Li G, Zhang W. Update on the birth weight standard and its diagnostic value in small for gestational age (SGA) infants in China. J Matern Fetal Neonatal Med. 2017;30:801–7.
29. Campbell EE, Dworatzek PD, Penava D, de Vrijer B, Gilliland J, Matthews JI, et al. Factors that influence excessive gestational weight gain: moving beyond assessment and counselling. J Matern Fetal Neonatal Med. 2016;29:3527–31.
30. Manera F, Fernandes RC, Hofelmann DA. Trajectory patterns of gestational weight gain. J Am Nutr Assoc. 2023;42:643–50.
31. Lin D, Huang Z, Fan D, Chen G, Ye S, Wu S, et al. Association between gestational weight gain and perinatal outcomes among twin gestations based on the 2009 Institute of medicine (IOM) guidelines: a systematic review. J Matern Fetal Neonatal Med. 2022;35:6527–41.
32. Ozcan T, Bacak SJ, Zozzaro-Smith P, Li D, Sagcan S, Seligman N, et al. Assessing weight gain by the 2009 Institute of medicine guidelines and perinatal outcomes in twin pregnancy. Matern Child Health J. 2017;21:509–15.
33. Brown JE, Schloesser PT. Prepregnancy weight status, prenatal weight gain, and the outcome of term twin gestations. Am J Obstet Gynecol. 1990;162:182–6.
34. Gaillard R, Steegers EA, Franco OH, Hofman A, Jaddoe VW. Maternal weight gain in different periods of pregnancy and childhood cardio-metabolic outcomes. The generation R study. Int J Obes (Lond). 2015;39:677–85.
35. Karachaliou M, Georgiou V, Roumeliotaki T, Chalkiadaki G, Daraki V, Koinaki S, et al. Association of trimester-specific gestational weight gain with fetal growth, offspring obesity, and cardiometabolic traits in early childhood. Am J Obstet Gynecol. 2015;212:e5021–14.
36. Holland E, Moore Simas TA, Doyle Curiale DK, Liao X, Waring ME. Self-reported pre-pregnancy weight versus weight measured at first prenatal visit: effects on categorization of pre-pregnancy body mass index. Matern Child Health J. 2013;17:1872–8.
37. Nichols AR, Haeri S, Rudine A, Burns N, Rathouz PJ, Hedderson MM, et al. Prenatal weight change trajectories and perinatal outcomes among twin gestations. Am J Perinatol. 2024;41:1445–54.
38. Ashtree DN, Osborne DA, Lee A, Umstad MP, Craig JM, Scurrah KJ. Three trajectories of gestational weight gain identified in an Australian twin study. Eur J Obstet Gynecol Reprod Biol. 2022;275:24–30.
39. Nohr EA, Vaeth M, Baker JL, Sorensen T, Olsen J, Rasmussen KM. Combined associations of prepregnancy body mass index and gestational weight gain with the outcome of pregnancy. Am J Clin Nutr. 2008;87:1750–9.
40. Enomoto K, Aoki S, Toma R, Fujiwara K, Sakamaki K, Hirahara F. Pregnancy outcomes based on Pre-Pregnancy body mass index in Japanese women. PLoS ONE. 2016;11:e0157081.
41. Aune D, Saugstad OD, Henriksen T, Tonstad S. Maternal body mass index and the risk of fetal death, stillbirth, and infant death: a systematic review and meta-analysis. JAMA. 2014;311:1536–46.
42. He Y, Tam CH, Yuen LY, Catalano PM, Ma RC, Tam WH. Optimal gestational weight gain for Chinese women - analysis from a longitudinal cohort with childhood follow-up. Lancet Reg Health West Pac. 2021;13:100190.
43. Huang X, Tan H, Cai M, Shi T, Mi C, Lei J. Gestational weight gain in Chinese women -- results from a retrospective cohort in Changsha, China. BMC Pregnancy Childbirth. 2018;18:185.
44. Jahanfar S, Lim K, Oviedo-Joekes E. Stillbirth associated with birth weight discordance in twin gestations. J Obstet Gynaecol Can. 2019;41:52–8.

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