Preplanned Studies

Optimal Gestational Weight Gain for Women with Gestational Diabetes Mellitus — China, 2011–2021

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Summary

What is already known about this topic?

Joint effects of gestational weight gain (GWG) and hyperglycemia on adverse pregnancy outcomes suggest that lower optimal GWG is optimal for women with gestational diabetes mellitus (GDM). However, there is still a lack of guidelines.

What is added by this report?

Optimal weekly GWG range after diagnosis of GDM for underweight, normal-weight, overweight, and obese women was 0.37–0.56 kg/week, 0.26–0.48 kg/week, 0.19–0.32 kg/week, and 0.12–0.23 kg/week, respectively.

What are the implications for public health practice?

The findings may be used to inform prenatal counseling regarding optimal gestational weight gain for women with gestational diabetes mellitus, and suggest the need for weight gain management.

Excessive gestational weight gain (GWG) and hyperglycemia can have additive effects on adverse pregnancy outcomes, suggesting that optimal GWG might be lower for women with gestational diabetes mellitus (GDM) (*1*). However, there is a lack of guidelines for GWG among women with GDM. This multicenter cohort study aimed to determine the optimal GWG ranges after diagnosis for Chinese women with GDM and evaluate whether the new ranges could effectively reduce adverse outcomes. Data were extracted through electronic medical record systems at seven regional tertiary hospitals in China. Weekly GWG after diagnosis was calculated using the average weight gain each week from diagnosis of GDM to delivery. Optimal weekly GWG ranges were constructed for each pre-pregnancy body mass index (BMI) group by identifying the ranges that had relatively lower incidence of adverse outcomes. The proposed ranges were found to be associated with reduced adverse outcomes. Compared with the ranges of the National Academy of Medicine (NAM, previously called the Institute of Medicine) (*2*), the new ranges reduced the lower limits of GWG without causing additional risks of adverse outcomes and lowered the upper limit as well to avoid higher occurrence of large for gestational age births and macrosomia. These findings may inform prenatal counseling regarding optimal GWG after diagnosis of GDM and suggest the need for weight gain management.

Based on the previous work of Chinese Pregnant Women Cohort Study (CPWCS), a retrospective cohort study was conducted to extract data from electronic medical record systems from 2011 to 2021 in seven tertiary hospitals from Beijing, Zhejiang, Hebei, Shandong, Guizhou, and Shaanxi (*3*). A total of 11,168 women with GDM were included in this study. GDM was diagnosed according to the criteria of the International Association of Diabetes and Pregnancy Study Group (*4*). Previous evidence suggests that GWG is linear during the second and third trimesters of pregnancy (*2*,*5*), so the weekly GWG after diagnosis was calculated using the average weight gain each week from diagnosis of GDM to delivery. Adverse outcomes included full-term low birth weight, macrosomia, small for gestational age (SGA), large for gestational age (LGA), and preterm birth. An infant with a birth weight <2,500 g and delivered at ≥37 weeks was classified as having a full-term low birth weight, and with a birth weight >4,000 g was classified as having macrosomia. SGA and LGA were defined according to Chinese standards, referring to birth weight below the 10th percentile for gestational age or above the 90th percentile for gestational age, respectively (*6*). Preterm birth was defined as birth occurring prior to 37 weeks gestation.

The recommended ranges of weekly GWG for women with GDM were constructed using an outcome-based approach. The main idea of this

approach was to define the GWG ranges with the relatively lower incidence of adverse outcomes as the optimal ones, based on the thresholds of GWG below or above which the adverse outcome increased (7–9). The usual procedure was to group GWG at certain intervals and then find the intervals with lower incidence of adverse outcomes compared to others. In this study, for each maternal pre-pregnancy BMI group (defined by the standards for Chinese adults), weekly GWG after diagnosis of GDM was first divided into groups by an interval of 0.10 kg/week, and the number and incidence of adverse outcomes were calculated at each interval. The intervals with lower incidence compared with others were further subdivided by an interval of 0.05 kg/week. Similarly, the groups in 0.05 intervals with lower incidence were further subdivided by an interval of 0.02 kg/week and 0.01 kg/week sequentially. Finally, the optimal ranges accurate to 0.01 kg/week with lower risks of adverse outcomes were confirmed through groups divided by an interval of 0.01.

To verify the obtained optimal ranges, logistic regression was used to calculate the odds ratios (*OR*s) for each adverse outcome for the inadequate and excessive GWG groups, with the adequate GWG group as the reference. To compare the performance between the new ranges and NAM ranges, incidences of adverse outcomes across different groups of adequate GWG according to these two recommendations were also compared. Three sensitivity analyses were conducted. First, potential confounders (e.g., maternal age, drug treatment after diagnosis) were adjusted in the model when analyzing the association between GWG status and adverse outcomes. Subgroup analyses were also conducted by region. Additionally, subgroup analyses and the comparison with NAM were reconducted by excluding full-term low birth weight from outcomes of interest, as the great disparity of incidence it caused might affect the robustness of the results. Data analyses were conducted using R software (Version 4.0.3; John Chambers and colleagues, Jersey City, NJ, USA). Statistical significance was set at a two-sided *P*-value <0.05. Further details on the methods can be found in the supplementary file.

A total of 11,168 women were included (see Supplementary Figure S1, available in https://weekly.chinacdc.cn/), with a mean age of 31.0 [standard deviation (SD): 4.4] years and a mean gestational age of 38.7 (SD: 1.4) weeks. The sample was categorized into four weight groups: underweight (*n*=810), normal weight (*n*=6,835), overweight (*n*=2,775), and obesity (*n*=748; see Table 1). The incidence of adverse pregnancy outcomes ranged from 1.1% to 12.0%. Regional distribution is presented in Supplementary Table S1 (available in https://weekly.chinacdc.cn/).

In the underweight group, when the weekly GWG was less than 0.37 kg/week, the incidence of full-term low birth weight and preterm birth both increased. Among groups with GWG ≥0.56 kg/week, the incidence of LGA, macrosomia, and preterm birth increased. Thus, the optimal GWG range was 0.37–0.56 kg/week. Similarly, in the normal weight group, the optimal range was 0.26–0.48 kg/week to keep the incidence of adverse outcomes at a lower level. In the overweight group, when the GWG was less than 0.19 kg/week, the incidences of SGA, full-term low birth weight, and preterm birth all increased substantially. When the weekly weight gain was higher than 0.32 kg/week, the incidence of LGA and preterm birth showed a large increase. Therefore, the optimal

TABLE 1. Maternal characteristics and adverse pregnancy outcomes of all participants and in different pre-pregnancy body mass index (BMI) groups.

Characteristic and outcomes	All Population (*N* =11,168)	Underweight (*N*=810)	Normal weight (*N*=6,835)	Overweight (*N*=2,775)	Obesity (*N*=748)
Maternal age [years (mean±SD)]	31.0±4.4	29.7 ±4.2	31.0±4.3	31.3±4.5	31.1±4.4
Nulliparous, *n* (%)	8,461 (75.8)	691 (85.3)	5,270 (77.1)	1,980 (71.4)	520 (69.5)
Gestational age [weeks(mean±SD)]	38.7±1.4	29.7±4.2	31.0±4.3	38.6±1.5	38.4±1.5
Male neonates, *n* (%)	4,430 (53.4)	360 (57.8)	2,663 (52.8)	1,095 (53.2)	312 (54.9)
Adverse outcomes, *n* (%)					
Preterm birth	574 (5.1)	32 (4.0)	347 (5.1)	144 (5.2)	51 (6.8)
Small size for gestational age	623 (5.6)	70 (8.6)	383 (5.6)	141 (5.1)	29 (3.9)
Large size for gestational age	1,338 (12.0)	44 (5.4)	689 (10.1)	447 (16.1)	158 (21.1)
Full-term low birth weight	121 (1.1)	9(1.1)	68 (1.0)	36 (1.3)	8 (1.1)
Macrosomia	764 (6.8)	26 (3.2)	403 (5.9)	254 (9.2)	81 (10.8)

weekly weight gain for the overweight group was 0.19–0.32 kg/week. The range in the obesity group was 0.12–0.23 kg/week, which was able to avoid macrosomia and LGA (see Supplementary Tables S2–S5, available in https://weekly.chinacdc.cn/).

GWG status after GDM diagnosis was categorized according to the ranges proposed. The odds ratios (*OR*s) of inadequate and excessive GWG for each adverse pregnancy outcome, with the adequate GWG as the reference group, are presented in Table 2. Inadequate GWG defined by the new range was associated with increased risks of preterm birth, while excessive GWG was associated with higher risks of preterm birth, LGA and macrosomia. The associations were not altered after adjusting for potential confounders and were similar among different regions (Supplementary Figure S2, available in https://weekly.chinacdc.cn/). When comparing with the NAM ranges, reduced lower limits of GWG did not increase risks of adverse outcomes in the four groups. In the obesity group, women with adequate GWG according to the new ranges had lower risks of LGA and macrosomia compared to the part of NAM ranges discrepant with the new ranges (Supplementary Tables S6–S9, available in https://weekly.chinacdc.cn/).

DISCUSSION

This multicenter study proposed optimal weekly GWG ranges after diagnosis of GDM among Chinese populations using an outcome-based approach. Inadequate GWG, as defined by the new range, was associated with increased preterm birth risks, while excessive GWG was associated with increased risks of preterm birth, LGA, and macrosomia. The new ranges reduced the lower limits of GWG without causing additional risks and modification of the upper limits avoided higher occurrences of LGA and macrosomia. This study provides tailored GWG recommendations to promote optimal pregnancy outcomes for women with GDM, and enables clinicians to give targeted weight control suggestions and counsel patients week to week regarding their performance.

Only a few studies have attempted to propose GWG targets for GDM pregnancies, and most of them provided recommendations on the total GWG during the entire pregnancy without distinguishing before and after GDM diagnosis. As GDM women cannot be identified before diagnosis, GWG ranges should be proposed after diagnosis. Although the previous studies had different methods and results, studies focusing on

TABLE 2. Association between GWG status and adverse outcomes in different pre-pregnancy BMI groups.*

Pre-pregnancy BMI (kg/m^2)	GWG status	SGA			LGA			Full-termlow birth weight			Macrosomia			Preterm birth		
		OR	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*
Underweight (<18.5)	Adequate	1.00			1.00			1.00			1.00			1.00		
	Inadequate	1.59	0.90, 2.88	0.116	1.25	0.58, 2.74	0.573	0.46	0.06, 2.36	0.369	0.79	0.27, 2.22	0.650	3.09	1.30, 8.57	0.017†
	Excessive	1.05	0.52, 2.08	0.884	1.75	0.81, 3.88	0.154	0.98	0.19, 4.49	0.979	1.81	0.72, 4.74	0.212	1.28	0.39, 4.14	0.676
Normal weight (18.5–23.9)	Adequate	1.00			1.00			1.00			1.00			1.00		
	Inadequate	1.20	0.92, 1.55	0.175	0.66	0.52, 0.82	<0.001†	1.30	0.69, 2.44	0.406	0.59	0.43, 0.80	<0.001†	1.88	1.42, 2.50	<0.001†
	Excessive	1.14	0.89, 1.47	0.297	1.33	1.12, 1.59	0.001†	1.42	0.80, 2.56	0.232	1.48	1.18, 1.85	<0.001†	1.55	1.18, 2.04	0.002†
Overweight (24.0–27.9)	Adequate	1.00			1.00			1.00			1.00			1.00		
	Inadequate	1.11	0.67, 1.87	0.693	0.53	0.37, 0.75	<0.001†	1.65	0.46, 7.68	0.471	0.44	0.28, 0.70	<0.001†	2.98	1.62, 5.94	<0.001†
	Excessive	0.92	0.58 1.50	0.735	1.16	0.88, 1.52	0.289	2.78	0.97, 11.70	0.095	1.08	0.78, 1.52	0.646	2.20	1.24, 4.27	0.012†
Obesity (≥28.0)	Adequate	1.00			1.00			1.00			1.00			1.00		
	Inadequate	0.52	0.10, 2.44	0.408	0.86	0.39, 1.92	0.711	–	–	0.992	1.20	0.43, 3.66	0.730	1.37	0.50, 4.10	0.553
	Excessive	1.13	0.42, 3.95	0.824	2.04	1.13, 3.96	0.024†	0.57	0.13, 3.95	0.498	2.05	0.93, 5.44	0.105	1.02	0.44, 2.75	0.973

Abbreviation: BMI=body mass index; GWG=gestational weight gain; SGA=small for gestational age; LGA=large for gestational age; *OR*=odds ratio; *CI*=confidence interval.

* GWG status was judged using the newly obtained optimal ranges.

† *P*<0.05.

"–" means that Model for full-term low birth weight in this group cannot be well fitted due to sample size.

exploration of optimal range in China and abroad have supported stricter optimal GWG ranges than the NAM standards to improve pregnancy outcomes (*10*–*11*). Considering the great impact of GWG during the second and third trimesters on adverse outcomes, proposing an optimal GWG after diagnosis of GDM rather than the total GWG allows clinicians to give targeted suggestions and counsel their patients on their weekly GWG regarding their weight control performance. Only one study in China could be compared with this study for similar methods (*9*). However, there were limitations in their study, such as a single-center design and an insufficient number of samples to obtain a statistically significant lower limit. Our analyses indicated that inappropriate GWG under the new ranges was associated with increased adverse outcomes, which were similar to most relevant reports on the associations between GWG and prenatal outcomes.

The new ranges reduced the lower limits of weekly GWG compared with the NAM ranges. The new ranges did not significantly increase the risks of any adverse outcomes and excluded women with a higher occurrence of adverse outcomes, suggesting that weight management stricter than the NAM standard during pregnancy might be more beneficial among Chinese individuals with GDM. Previous research has found that people of Asian descent tend to possess a lower BMI and a higher percentage of body fat than white populations, along with a higher susceptibility of metabolic conditions (*12*). GWG standards constructed by the Chinese Nutrition Society (CNS) for singleton pregnancy without pregnancy complications were also generally lower than the NAM standards (*13*). Evidence supports that GDM itself is an independent risk factor for adverse outcomes and metabolic changes induced by GDM combining with excess gestational weight gain could have joint effects. Thus, the evidence above supports that optimal GWG ranges for women with GDM in China should be different and they would benefit from a more tailored recommendation.

Results of this study showed consistency with the CNS guidelines among women categorized as pre-pregnancy underweight or normal weight, but the upper and lower limits of the recommended ranges for groups of overweight and obesity were lower. To effectively avoid the adverse effects of the three risk factors (pre-pregnancy obesity, excessive GWG and GDM), researchers suggested that stricter weight management might offer additional benefits for women with pre-pregnancy obesity. The co-occurrence of pre-pregnancy obesity and gestational abnormal glucose metabolism was found to further worsen adverse pregnancy outcomes (such as LGA and macrosomia) compared to a single condition alone. One possible explanation is that higher nutritional status may exaggerate insulin resistance and worsen GDM outcomes. Pre-pregnancy obese women with adequate GWG within our ranges had a lower risk of LGA and macrosomia, and women in the overweight group with adequate GWG within our ranges also had a lower risk of preterm birth. These results indicate that the new ranges are more beneficial for GDM women with pre-pregnancy overweight and obesity, as adverse outcomes need to be prevented intensively in this population.

This study has several limitations. First, we did not adjust for glycemic control in the analyses since these data were not collected. However, we attempted to minimize its impact by adjusting the variable of drug treatment in the models. Second, we did not include the adverse outcomes of long-term outcomes such as postpartum complications or offspring diseases, which should be explored in the future. Third, the sample sizes of the underweight or obese groups were limited and the results await further validation. Additionally, conclusions of this study came from observational studies and the ranges need to be further validated by intervention studies in the future.

In conclusion, this multicenter study established lower optimal GWG ranges for women with GDM. Clinics should provide additional targeted advice after GDM diagnosis to help women maintain weekly weight gains within a reasonable range. As management of weight gain after GDM diagnosis is an important component of GDM intervention, further validation of our findings is also needed in the future.

Conflicts of interest: No conflicts of interest.

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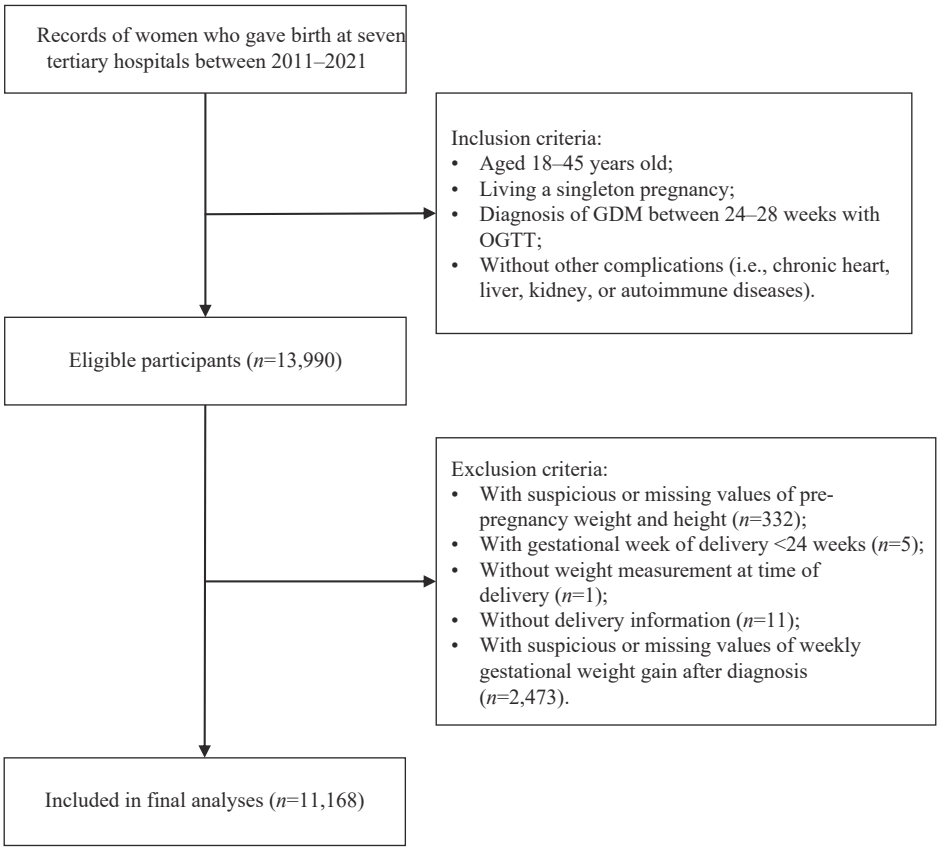
SUPPLEMENTARY MATERIAL

Data Collection and Data Processing

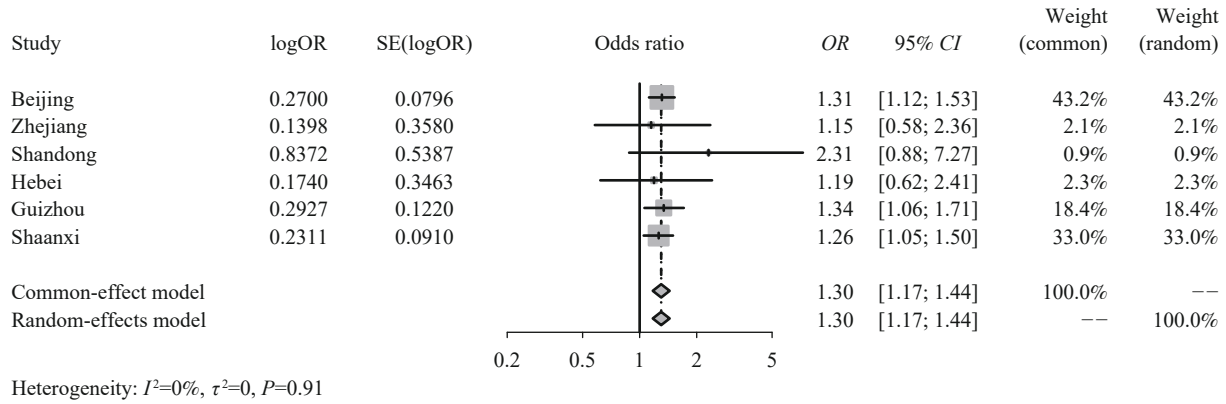
Based on the previous work of Chinese Pregnant Women Cohort Study (CPWCS), this retrospective cohort study selected seven regional tertiary hospitals from China after considering the standard level of clinical treatment, data quality, hospital's willingness to participate, and cooperation between the hospital and the researchers. Information was extracted from electronic medical record systems from 2011 to 2021. Because weight was not routinely measured and recorded at the time of 75 g oral glucose tolerance test (OGTT), we widened the time period to get more cases with complete information. We included 13,990 participants, of whom 2,822 were excluded. Finally, 11,168 (79.8%) women with gestational diabetes mellitus (GDM) were included in this study (See Supplementary Figure S1).

Associations Between GWG Status and Adverse Outcomes

We also conducted subgroup analyses to test whether the associations between adverse outcomes and inappropriate gestational weight gain (GWG) according to the newly obtained ranges were different among regions. Considering the small sample size in some regions, the odds ratios (*OR*s) for any adverse outcome were calculated for the inappropriate group (combining inadequate GWG group and excessive GWG group), with the adequate group as the reference. According to the pooled results of meta-analysis (Supplementary Figure S2), inappropriate GWG according to the newly obtained range was associated with increased risks of adverse perinatal outcomes, indicating no heterogeneity among different regions (I^2=0, P=0.91). After removing participants from Beijing, the results in the remaining regions also showed no heterogeneity (I^2=0, P=0.83). And after excluding full-term low birthweight from outcomes of interest, the result of meta-analysis remained similar as well (I^2=0, P=0.91).



SUPPLEMENTARY FIGURE S1. Flowchart of participants in the study.
Abbreviation: GDM=gestational diabetes mellitus; OGTT=oral glucose tolerance test.



SUPPLEMENTARY FIGURE S2. Associations between adverse outcomes and inappropriate GWG according to the newly obtained ranges by different regions.
Abbreviation: *OR*=odds ratio; *CI*=confidence interval; GWG=gestational weight gain.

Comparisons of Performance Between the New Ranges and NAM Ranges

To assess whether our newly obtained ranges were more feasible for GDM women than the National Academy of Medicine (NAM) recommended range, we compared the incidences of adverse outcomes across groups of adequate GWG according to our ranges and NAM ranges.

For normal weight group and overweight group with relatively large sample sizes, we calculated the odds ratio of different adverse outcomes by logistic regression for the discrepant ranges of the two targets, with the overlapping range (regarded as adequate in both recommendations) as the reference. For underweight and obesity groups with relatively small sample sizes, we calculated the odds ratio of adverse outcomes for the discrepant ranges, with the new ranges or the NAM ranges as the reference. And in these two groups, adverse outcomes were grouped into two types: outcomes positively associated with weekly GWG [large for gestational age (LGA) and macrosomia] and outcomes negatively associated with GWG [small for gestational age (SGA), full-term low birth weight, and preterm birth]. These analyses were aimed to find out whether the changes we made comparing to the NAM recommended ranges would have a lower occurrence of adverse outcomes.

In underweight and the normal weight groups, we found out that GWG range below the lower limits of the NAM did not significantly increase the risk of adverse outcomes. However, in GWG range group below our lower limit, the incidence of preterm birth increased significantly (*OR*: 2.07, 95% *CI*: 1.49, 2.94) in the normal weight group. Similar to the overweight group, the part of the new ranges discrepant with the NAM's did not lead to a significant change, but GWG above 0.33 kg/week (almost close to our upper limit 0.32 kg/week) or below our lower limit will lead to increased risks of preterm birth (*OR*: 2.10, 95% *CI*: 1.10, 4.53; *OR*: 2.88, 95% *CI*: 1.47, 6.35). In obesity group, women with adequate GWG under our new ranges had lower risks of LGA and macrosomia compared to the part of the NAM ranges above our upper limit (*OR*: 2.76, 95% *CI*: 1.20, 6.50). And the reduced lower limit in the obesity group did not cause extra risks as well. After removing full-term low birth weight from the outcomes of interest, the results in the four groups remained the same as the newly defined lower and upper limits did not cause extra risks.

SUPPLEMENTARY TABLE S1. Geographic distribution of 11,168 participants by different pre-pregnancy body mass index (BMI) groups.

Pre-pregnancy BMI group	Beijing *n* (%)	Zhejiang *n* (%)	Shandong *n* (%)	Hebei *n* (%)	Guizhou *n* (%)	Shaanxi *n* (%)
Underweight	316 (7.1)	20 (9.9)	4 (2.7)	26 (7.9)	152 (7.4)	292 (7.3)
Normal Weight	2,775 (62.1)	131 (64.9)	65 (44.2)	156 (47.4)	1,231 (60.1)	2,477 (62.3)
Overweight	1,138 (25.5)	45 (22.3)	48 (32.7)	101 (30.7)	495 (24.2)	948 (23.8)
Obesity	238 (5.3)	6 (3.0)	30 (20.4)	46 (14.0)	170 (8.3)	258 (6.5)
Total	4,467	202	147	329	2,048	3,975

Abbreviation: BMI=body mass index.

SUPPLEMENTARY TABLE S2. Incidence for adverse outcomes in each GWG category (kg/week) in the underweight group.

GWG category (kg/week)	*N*=810	SGA *n* (%)	LGA *n* (%)	Full-term low birth weight *n* (%)	Macrosomia *n* (%)	Preterm birth *n* (%)
<0.32	240	26 (10.8)	13 (5.4)	2 (0.8)	5 (2.1)	18 (7.5)
0.32–0.37	73	8 (11.0)	3 (4.1)	0 (0.0)	2 (2.7)	2 (2.7)
0.37–0.39	25	3 (12.0)	1 (4.0)	0 (0.0)	1 (4.0)	0 (0.0)
0.39–0.41	30	4 (13.3)	1 (3.3)	2 (6.7)	1 (3.3)	0 (0.0)
0.41–0.43	35	5 (14.3)	3 (8.6)	1 (2.9)	1 (2.9)	1 (2.9)
0.43–0.45	32	1 (3.1)	2 (6.2)	0 (0.0)	2 (6.2)	2 (6.2)
0.45–0.47	41	1 (2.4)	1 (2.4)	1 (2.4)	0 (0.0)	0 (0.0)
0.47–0.49	22	2 (9.1)	1 (4.5)	0 (0.0)	1 (4.5)	1 (4.5)
0.49–0.50	11	1 (9.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (9.1)
0.50–0.51	20	1 (5.0)	1 (5.0)	0 (0.0)	0 (0.0)	0 (0.0)
0.51–0.52	12	0 (0.0)	1 (8.3)	0 (0.0)	1 (8.3)	0 (0.0)
0.52–0.53	12	2 (16.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
0.53–0.54	15	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
0.54–0.55	12	0 (0.0)	1 (8.3)	0 (0.0)	1 (8.3)	0 (0.0)
0.55–0.56	11	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (9.1)
0.56–0.57	12	1 (8.3)	0 (0.0)	0 (0.0)	0 (0.0)	1 (8.3)
0.57–0.58	14	0 (0.0)	1 (7.1)	0 (0.0)	1 (7.1)	0 (0.0)
0.58–0.59	13	1 (7.7)	2 (15.4)	1 (7.7)	1 (7.7)	0 (0.0)
0.59–0.60	0	–	–	–	–	–
≥0.60	180	14 (7.8)	13 (7.2)	2 (1.1)	9 (5.0)	5 (2.8)

Abbreviation: GWG=gestational weight gain; SGA=small for gestational age; LGA=large for gestational age.

SUPPLEMENTARY TABLE S3. Incidence for adverse outcomes in each GWG category (kg/week) in the normal weight group.

GWG category (kg/week)	*N*=6,835	SGA *n* (%)	LGA *n* (%)	Full-term low birth weight *n* (%)	Macrosomia *n* (%)	Preterm birth *n* (%)
<0.23	1,587	102 (6.4)	101 (6.4)	17 (1.1)	49 (3.1)	108 (6.8)
0.23–0.24	103	6 (5.8)	3 (2.9)	1 (1.0)	2 (1.9)	5 (4.9)
0.24–0.26	195	10 (5.1)	22 (11.3)	2 (1.0)	12 (6.2)	10 (5.1)
0.26–0.28	178	13 (7.3)	20 (11.2)	1 (0.6)	14 (7.9)	7 (3.9)
0.28–0.30	215	17 (7.9)	14 (6.5)	2 (0.9)	7 (3.3)	10 (4.7)
0.30–0.31	121	10 (8.3)	9 (7.4)	2 (1.7)	7 (5.8)	0 (0.0)
0.31–0.32	96	2 (2.1)	14 (14.6)	1 (1.0)	8 (8.3)	6 (6.2)
0.32–0.33	88	2 (2.3)	17 (19.3)	2 (2.3)	7 (8.0)	4 (4.5)
0.33–0.34	151	6 (4.0)	14 (9.3)	0 (0.0)	9 (6.0)	7 (4.6)
0.34–0.35	108	6 (5.6)	11 (10.2)	3 (2.8)	7 (6.5)	5 (4.6)
0.35–0.36	124	3 (2.4)	16 (12.9)	1 (0.8)	12 (9.7)	4 (3.2)
0.36–0.37	115	4 (3.5)	10 (8.7)	0 (0.0)	4 (3.5)	0 (0.0)
0.37–0.38	103	4 (3.9)	10 (9.7)	1 (1.0)	7 (6.8)	9 (8.7)
0.38–0.39	107	2 (1.9)	9 (8.4)	1 (0.9)	1 (0.9)	4 (3.7)
0.39–0.40	86	7 (8.1)	11 (12.8)	2 (2.3)	5 (5.8)	2 (2.3)
0.40–0.41	151	9 (6.0)	12 (7.9)	0 (0.0)	3 (2.0)	7 (4.6)
0.41–0.42	131	6 (4.6)	18 (13.7)	0 (0.0)	10 (7.6)	4 (3.1)
0.42–0.43	122	10 (8.2)	14 (11.5)	0 (0.0)	10 (8.2)	2 (1.6)
0.43–0.44	111	6 (5.4)	9 (8.1)	0 (0.0)	4 (3.6)	3 (2.7)
0.44–0.45	103	2 (1.9)	8 (7.8)	0 (0.0)	4 (3.9)	5 (4.9)
0.45–0.46	120	5 (4.2)	12 (10.0)	1 (0.8)	11 (9.2)	3 (2.5)
0.46–0.47	129	9 (7.0)	8 (6.2)	3 (2.3)	6 (4.7)	1 (0.8)
0.47–0.48	72	1 (1.4)	6 (8.3)	0 (0.0)	2 (2.8)	4 (5.6)
0.48–0.49	118	5 (4.2)	12 (10.2)	0 (0.0)	7 (5.9)	7 (5.9)
0.49–0.50	82	7 (8.5)	6 (7.3)	2 (2.4)	2 (2.4)	4 (4.9)
0.50–0.51	217	8 (3.7)	28 (12.9)	1 (0.5)	17 (7.8)	11 (5.1)
0.51–0.52	59	3 (5.1)	5 (8.5)	0 (0.0)	1 (1.7)	1 (1.7)
0.52–0.53	84	8 (9.5)	10 (11.9)	2 (2.4)	3 (3.6)	3 (3.6)
0.53–0.54	132	8 (6.1)	20 (15.2)	1 (0.8)	17 (12.9)	1 (0.8)
0.54–0.55	106	9 (8.5)	12 (11.3)	4 (3.8)	9 (8.5)	3 (2.8)
0.55–0.60	379	23 (6.1)	47 (12.4)	1 (0.3)	25 (6.6)	16 (4.2)
0.60–0.65	312	14 (4.5)	33 (10.6)	6 (1.9)	24 (7.7)	18 (5.8)
0.65–0.70	255	11 (4.3)	44 (17.3)	1 (0.4)	29 (11.4)	14 (5.5)
≥0.70	775	45 (5.8)	104 (13.4)	10 (1.3)	68 (8.8)	59 (7.6)

Abbreviation: GWG=gestational weight gain; SGA=small for gestational age; LGA=large for gestational age.

SUPPLEMENTARY TABLE S4. Incidence for adverse outcomes in each GWG category (kg/week) in the overweight group

GWG category (kg/week)	*N*=2,775	SGA *n* (%)	LGA *n* (%)	Full-term low birth weight *n* (%)	Macrosomia *n* (%)	Preterm birth *n* (%)
<0.10	409	25 (6.1)	33 (8.1)	3 (0.7)	19 (4.6)	35 (8.6)
0.10–0.15	133	6 (4.5)	10 (7.5)	1 (0.8)	5 (3.8)	6 (4.5)
0.15–0.16	47	0 (0.0)	9 (19.1)	0 (0.0)	4 (8.5)	1 (2.1)
0.16–0.17	35	4 (11.4)	3 (8.6)	1 (2.9)	1 (2.9)	2 (5.7)
0.17–0.18	26	3 (11.5)	5 (19.2)	2 (7.7)	1 (3.8)	1 (3.8)
0.18–0.19	36	4 (11.1)	5 (13.9)	0 (0.0)	2 (5.6)	3 (8.3)
0.19–0.20	19	0 (0.0)	3 (15.8)	0 (0.0)	2 (10.5)	0 (0.0)
0.20–0.21	54	2 (3.7)	7 (13.0)	0 (0.0)	5 (9.3)	1 (1.9)
0.21–0.22	25	0 (0.0)	2 (8.0)	0 (0.0)	1 (4.0)	0 (0.0)
0.22–0.23	36	2 (5.6)	8 (22.2)	1 (2.8)	5 (13.9)	2 (5.6)
0.23–0.24	39	2 (5.1)	5 (12.8)	0 (0.0)	2 (5.1)	2 (5.1)
0.24–0.25	13	0 (0.0)	3 (23.1)	0 (0.0)	1 (7.7)	0 (0.0)
0.25–0.26	42	3 (7.1)	9 (21.4)	0 (0.0)	4 (9.5)	0 (0.0)
0.26–0.27	44	1 (2.3)	5 (11.4)	0 (0.0)	1 (2.3)	1 (2.3)
0.27–0.28	45	3 (6.7)	10 (22.2)	0 (0.0)	7 (15.6)	1 (2.2)
0.28–0.29	43	3 (7.0)	6 (14.0)	0 (0.0)	4 (9.3)	3 (7.0)
0.29–0.30	32	2 (6.2)	9 (28.1)	1 (3.1)	7 (21.9)	1 (3.1)
0.30–0.31	65	5 (7.7)	9 (13.8)	1 (1.5)	8 (12.3)	0 (0.0)
0.31–0.32	31	2 (6.5)	5 (16.1)	0 (0.0)	3 (9.7)	1 (3.2)
0.32–0.33	42	0 (0.0)	9 (21.4)	0 (0.0)	2 (4.8)	3 (7.1)
0.33–0.34	63	3 (4.8)	5 (7.9)	1 (1.6)	2 (3.2)	3 (4.8)
0.34–0.35	30	0 (0.0)	4 (13.3)	0 (0.0)	3 (10.0)	2 (6.7)
0.35–0.36	66	2 (3.0)	13 (19.7)	1 (1.5)	8 (12.1)	3 (4.5)
0.36–0.37	39	1 (2.6)	8 (20.5)	1 (2.6)	4 (10.3)	2 (5.1)
0.37–0.38	40	2 (5.0)	6 (15.0)	0 (0.0)	3 (7.5)	4 (10.0)
0.38–0.39	63	4 (6.3)	16 (25.4)	1 (1.6)	10 (15.9)	1 (1.6)
0.39–0.40	46	3 (6.5)	10 (21.7)	0 (0.0)	7 (15.2)	1 (2.2)
0.40–0.45	192	5 (2.6)	28 (14.6)	2 (1.0)	18 (9.4)	8 (4.2)
0.45–0.50	170	8 (4.7)	36 (21.2)	2 (1.2)	19 (11.2)	9 (5.3)
0.50–0.55	198	12 (6.1)	40 (20.2)	2 (1.0)	28 (14.1)	9 (4.5)
0.55–0.60	140	5 (3.6)	22 (15.7)	4 (2.9)	13 (9.3)	6 (4.3)
≥0.60	512	29 (5.7)	104 (20.3)	12 (2.3)	55 (10.7)	33 (6.4)

Abbreviation: GWG=gestational weight gain; SGA=small for gestational age; LGA=large for gestational age.

SUPPLEMENTARY TABLE S5. Incidence for adverse outcomes in each GWG category (kg/week) in the obesity group

GWG category (kg/week)	*N*=748	SGA *n* (%)	LGA *n* (%)	Full-term low birth weight *n* (%)	Macrosomia *n* (%)	Preterm birth *n* (%)
<0.00	60	0 (0.0)	7 (11.7)	0 (0.0)	4 (6.7)	5 (8.3)
0.00–0.05	22	2 (9.1)	6 (27.3)	0 (0.0)	4 (18.2)	2 (9.1)
0.05–0.10	32	1 (3.1)	2 (6.2)	0 (0.0)	1 (3.1)	1 (3.1)
0.10–0.11	7	0 (0.0)	1 (14.3)	0 (0.0)	1 (14.3)	1 (14.3)
0.11–0.12	8	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (25.0)
0.12–0.13	8	2 (25.0)	0 (0.0)	1 (12.5)	0 (0.0)	1 (12.5)
0.13–0.14	8	1 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
0.14–0.15	10	0 (0.0)	3 (30.0)	0 (0.0)	1 (10.0)	2 (20.0)
0.15–0.16	9	1 (11.1)	0 (0.0)	1 (11.1)	0 (0.0)	0 (0.0)
0.16–0.17	9	0 (0.0)	1 (11.1)	0 (0.0)	1 (11.1)	1 (11.1)
0.17–0.18	6	0 (0.0)	1 (16.7)	0 (0.0)	0 (0.0)	1 (16.7)
0.18–0.19	7	0 (0.0)	1 (14.3)	0 (0.0)	1 (14.3)	0 (0.0)
0.19–0.20	8	0 (0.0)	1 (12.5)	0 (0.0)	1 (12.5)	0 (0.0)
0.20–0.21	12	0 (0.0)	4 (33.3)	0 (0.0)	1 (8.3)	0 (0.0)
0.21–0.22	9	0 (0.0)	1 (11.1)	0 (0.0)	1 (11.1)	1 (11.1)
0.22–0.23	8	0 (0.0)	1 (12.5)	0 (0.0)	0 (0.0)	0 (0.0)
0.23–0.24	14	0 (0.0)	5 (35.7)	0 (0.0)	2 (14.3)	1 (7.1)
0.24–0.25	10	0 (0.0)	2 (20.0)	0 (0.0)	1 (10.0)	0 (0.0)
0.25–0.26	18	1 (5.6)	6 (33.3)	1 (5.6)	4 (22.2)	2 (11.1)
0.26–0.27	9	0 (0.0)	3 (33.3)	0 (0.0)	0 (0.0)	0 (0.0)
0.27–0.28	18	2 (11.1)	4 (22.2)	1 (5.6)	1 (5.6)	2 (11.1)
0.28–0.29	7	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (14.3)
0.29–0.30	14	1 (7.1)	4 (28.6)	0 (0.0)	1 (7.1)	0 (0.0)
0.30–0.35	53	0 (0.0)	11 (20.8)	0 (0.0)	7 (13.2)	5 (9.4)
0.35–0.40	59	1 (1.7)	13 (22.0)	0 (0.0)	8 (13.6)	3 (5.1)
≥ 0.40	323	17 (5.3)	81 (25.1)	4 (1.2)	41 (12.7)	20 (6.2)

Abbreviation: GWG=gestational weight gain; SGA=small for gestational age; LGA=large for gestational age.

SUPPLEMENTARY TABLE S6. Adverse outcomes across groups of adequate GWG under the new range and NAM range in the underweight group.

GWG range (kg/week)	Outcomes positively associated with GWG			Outcomes negatively associated with GWG		
	OR	95% *CI*	*P*	*OR*	95% *CI*	*P*
Range above upper limit						
0.37–0.56*	1.00			1.00		
0.56–0.58†	0.85	0.05, 4.61	0.879	0.84	0.13, 3.07	0.818
Range below lower limit						
0.44–0.58§	1.00			1.00		
0.37–0.44¶	1.35	0.40, 4.18	0.605	2.00	0.89, 4.44	0.091

Abbreviation: GWG=gestational weight gain; *OR*=odds ratio; *CI*=confidence interval; NAM=National Academy of Medicine.
* The new range.
† Part of the NAM range above upper limit of the new range.
§ The NAM range.
¶ Part of the new range below the lower limit of the NAM range.

SUPPLEMENTARY TABLE S7. Adverse outcomes across groups of adequate GWG under the new range and NAM range in the normal weight group.

GWG range (kg/week)*	LGA			Macrosomia			Preterm birth			SGA			Full-term low birth weight		
	OR	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*
<0.26	0.68	0.53, 0.87	0.002§	0.63	0.45, 0.88	0.007§	2.07	1.49, 2.94	<0.001§	1.34	0.99, 1.82	0.065	1.77	0.83, 4.10	0.156
0.26-0.35	1.09	0.83, 1.43	0.532	1.17	0.82, 1.65	0.372	1.26	0.82, 1.94	0.289	1.30	0.90, 1.86	0.162	1.93	0.79, 4.80	0.145
0.35-0.48†	1.00			1.00			1.00			1.00			1.00		
0.48-0.50	0.93	0.54, 1.53	0.799	0.83	0.38, 1.60	0.613	1.73	0.84, 3.27	0.111	1.31	0.66, 2.38	0.403	1.67	0.25, 6.54	0.514
≥0.50	1.42	1.15, 1.76	0.001§	1.64	1.26, 2.16	<0.001§	1.71	1.22, 2.42	0.002§	1.27	0.94, 1.73	0.122	1.96	0.95, 4.43	0.084

Abbreviation: GWG=gestational weight gain; LGA=large for gestational age; SGA=small for gestational age; *OR*=odds ratio; *CI*=confidence interval; NAM=National Academy of Medicine.
* The new range was 0.26–0.48 kg/week and the NAM range was 0.35–0.50 kg/week, groups in the table were parts of the new ranges discrepant with NAM.
† The overlapping range of the two recommended ranges.
§ $P<0.05$.

SUPPLEMENTARY TABLE S8. Adverse outcomes across groups of adequate GWG under the new range and NAM range in the overweight group.

GWG range (kg/week)*	LGA			Macrosomia			Preterm birth			SGA			Full-term low birth weight		
	OR	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*	*OR*	*95% CI*	*P*
<0.19	0.50	0.32, 0.73	<0.001§	0.433	0.26, 0.71	<0.001§	2.88	1.47, 6.35	<0.001§	0.94	0.55, 1.64	0.822	1.79	0.43, 12.05	0.470
0.19–0.23	0.81	0.46, 1.39	0.455	0.915	0.45, 1.74	0.794	0.88	0.19, 2.99	0.847	0.47	0.14, 1.27	0.177	1.31	0.01, 13.78	0.827
0.23–0.32†	1.00			1.00			1.00			1.00			1.00		
0.32–0.33	1.22	0.52, 2.58	0.626	0.430	0.07, 1.48	0.257	2.95	0.63, 10.36	0.116	–	–	0.973	–	–	0.985
≥0.33	1.09	0.81, 1.49	0.575	1.074	0.74, 1.58	0.701	2.10	1.10, 4.53	0.037§	0.80	0.49, 1.36	0.393	3.10	0.92, 19.32	0.124

Abbreviation: GWG=gestational weight gain; LGA=large for gestational age; SGA=small for gestational age; *OR*=odds ratio; *CI*=confidence interval; NAM=National Academy of Medicine.
* The new range was 0.19–0.32 kg/week and the NAM range was 0.23–0.33 kg/week, groups in the table were parts of the new ranges discrepant with NAM.
† The overlapping range of the two recommended ranges.
§ $P<0.05$.
"–" means that models for SGA and full-term low birth weight in this group can't be well fitted due to sample size.

SUPPLEMENTARY TABLE S9. Adverse outcomes across groups of adequate GWG under the new range and NAM range in the obesity group.

GWG range (kg/week)	Outcomes positively associated with GWG			Outcomes negatively associated with GWG		
	OR	*95% CI*	*P*	*OR*	*95% CI*	*P*
Range above upper limit						
0.12–0.23*	1.00			1.00		
0.23–0.27†	2.76	1.20, 6.50	0.018**	0.92	0.24, 2.97	0.889
Range below lower limit						
0.17–0.27§	1.00			1.00		
0.12–0.17¶	0.34	0.10, 0.97	0.064	2.92	0.94, 9.53	0.065

Abbreviation: GWG=gestational weight gain; *OR*=odds ratio; *CI*=confidence interval; NAM=National Academy of Medicine.
* The new range.
† Part of the NAM range above upper limit of the new range.
§ The NAM range.
¶ Part of the new range below the lower limit of the NAM range.
** $P<0.05$.