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Maternal characteristics associated with gestational weight gain in France: a population-based, nationally representative study

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ABSTRACT

Objectives To provide nationally representative estimates of gestational weight gain (GWG) and identify maternal characteristics associated with inadequate GWG in France.

Design A population-based study using data from the French National Perinatal Survey: 2010 and 2016.

Setting All maternity units in metropolitan, mainland France (n=535 in 2010; n=493 in 2016).

Participants Singleton live births with GWG data (N=24 850).

Primary outcome measures GWG was calculated as end of pregnancy minus pre-pregnancy weight (kg) and categorised as 'insufficient', 'adequate', or 'excessive' using 2009 Institute of Medicine thresholds. Classification accounted for pre-pregnancy body mass index (BMI) (kg/m^2; underweight (<18.5), normal weight (18.5–24.9), overweight (25–29.9), obese (≥30)) and gestational age at birth. We estimated average GWG and the percentage of women in each GWG category. Polytomous logistic regression identified characteristics associated with GWG adequacy.

Results Average GWG was 13.0 kg (SD 5.6), with 26.8% of women gaining insufficiently, 37.0% adequately and 36.1% excessively. Among other factors, insufficient GWG was associated with underweight (vs normal weight; adjusted OR (aOR) 1.4, 95% CI 1.2 to 1.5) and obese (aOR 1.5, 95% CI 1.4 to 1.7) BMI. Excessive GWG was associated with overweight (aOR 2.8, 95% CI 2.6 to 3.1) and obese BMI (aOR 3.3, 95% CI 2.9 to 3.6). Examining obesity classes separately, odds of insufficient GWG increased from obesity class I to III, while odds of excessive GWG decreased from obesity class I to III. Primiparity (insufficient: aOR 0.9, 95% CI 0.9 to 1.0; excessive: aOR 1.2, 95% CI 1.2 to 1.3), maternal characteristics indicative of lower socioeconomic status, and continuing or quitting smoking during pregnancy were also associated with inadequate GWG.

Conclusions In France, insufficient and excessive GWG are common. For optimal outcomes, clinician education, with special attention to the needs of higher risk/vulnerable groups, is needed to ensure all women receive appropriate advice for recommended GWG.

Strengths and limitations of this study

► This is the first nationally representative study of risk factors for gestational weight gain (GWG) in France.
► The French National Perinatal Survey includes all maternity units in metropolitan, mainland France.
► Specially trained study midwives collected extensive, rigorous data through maternal interview and chart abstraction.
► The definition of GWG adequacy incorporated length of gestation, limiting potential bias due to the correlation between GWG and length of gestation.
► Some data (including pre-pregnancy body mass index and GWG) were self-reported and collected retrospectively, which could result in measurement error.

INTRODUCTION

Due to demographic and lifestyle changes, women are entering pregnancy with a higher body mass index (BMI) and gaining excessive pregnancy weight.[1–4] These trends are concerning as both healthy BMI[1 5] and adequate gestational weight gain (GWG) are important for optimal fetal growth and pregnancy/birth outcomes. Specifically, excessive GWG is associated with caesarean birth,[6 7] postpartum weight retention/obesity,[8 9] increased infant size[7 10] and childhood overweight/obesity.[11 12] Conversely, insufficient GWG is associated with decreased infant size[7 10 13] and preterm birth.[7] In 2009, the USA's Institute of Medicine (IOM; now National Academy of Medicine) updated GWG guidelines, stratified by maternal pre-pregnancy BMI, to improve care for the contemporary obstetric population.[1] While the current IOM guidelines provide a single recommendation for GWG for all women with obese pre-pregnancy BMI, whether separate guidelines are needed by obesity class is unclear due to insufficient evidence. Further,

the American College of Obstetricians and Gynecologists determined that evidence is lacking to recommend that women with obese BMI with GWG below the IOM recommendations but with an appropriately growing fetus should be encouraged to increase their GWG.[14]

Because GWG is modifiable and pregnant women interact frequently with healthcare providers, identification of factors associated with total GWG and inadequate GWG (insufficient or excessive) is necessary to target context-specific recommendations for GWG interventions/counselling. In addition to maternal pre-pregnancy BMI, numerous maternal factors, including sociodemographic characteristics, are potentially associated with GWG.[8 15–27] However, evidence gaps exist, as most studies of GWG risk factors were conducted in the USA[8 16 17 20 22 24 25] and many had a relatively small sample size (N<1000),[19 22 23 26 27] used GWG guidelines[8 16 17 19 22] or collected data prior to the 2009 IOM guidelines,[15 18 25] or focused narrowly on specific risk factors.[22–26] Therefore, additional research on risk factors related to GWG is needed in large, contemporary, diverse populations, specifically in nationally representative populations outside of the USA.

In France, both maternal pre-pregnancy BMI and the prevalence of inadequate GWG are increasing.[3 28 29] While previous French GWG studies evaluated adverse outcomes of GWG[12 30–32] or reported overviews of the main pregnancy indicators,[28 29] no study has comprehensively assessed GWG risk factors in France. Compared with the USA (where most previous studies on the association between risk factors for GWG were conducted), the French obstetric population differs on key factors related to weight and GWG (eg, lower BMI[28 33] and higher rates of smoking[28 34] in the French obstetric population) and benefits from the world's highest performing healthcare system based on a WHO study of overall efficiency.[35] Thus, the risk factors previously identified may not be relevant in France. To build on prior evidence within a more contemporary, robust, nationally representative cohort in a unique location and thereby inform local medical professionals providing care to pregnant women and international researchers evaluating consistency of risk factors across different cultural and organisational settings, our objectives were to provide population-based estimates of average GWG and the percentage of women achieving insufficient, adequate or excessive GWG, and identify maternal characteristics and social factors associated with mean GWG and insufficient and excessive GWG in France.

METHODS
Study design and population
We combined data from the 2010[29] and 2016[28] French National Perinatal Surveys (NPSs), which are routine, nationally representative surveys including all live and stillbirths in all maternity units in metropolitan, mainland France (n=535 in 2010; n=493 in 2016). In each survey,

data were collected during 1 week. Data collection, performed by trained study midwives, included a face-to-face interview of women prior to hospital discharge (2–3 days following birth) using a standardised questionnaire to obtain information related to sociodemographic characteristics and antenatal care and chart abstraction to obtain information on maternal and neonatal health and delivery.

After combining data from both years, the survey sample included 27 828 women (n=14 681 in 2010; n=13 147 in 2016). We excluded multiple births (n=221 in 2010; n=234 in 2016), pregnancy terminations (n=53 in 2010; n=52 in 2016) and stillbirths (n=76 in 2010; n=73 in 2016), which may have distinct GWG patterns. We also excluded women with missing (n=872 in 2010; n=1392 in 2016) or implausible GWG, defined as gain >50 kg or loss >30 kg[9 36] (n=4 in 2010; n=1 in 2016). Based on missing/implausible GWG, <10% of women with singleton live births in the NPS were excluded. Our final analysis included 24 850 women (n=13 455 in 2010; n=11 395 in 2016; figure 1).

GWG variables
Observed GWG (kg) was calculated based on women's self-reported end of pregnancy minus pre-pregnancy weight. Then, GWG adequacy (insufficient, adequate, excessive) was determined by maternal pre-pregnancy BMI (kg/m²; using self-reported height and pre-pregnancy weight; underweight (<18.5), normal weight (18.5–24.9), overweight (25–29.9), obese (≥30))[37] and was standardised across gestational ages using a previously described method[38 39] based on the assumptions underlying the 2009 GWG IOM guidelines, as detailed in table 1.

French guidelines for GWG (2007 French National Nutrition and Health Program (Programme National Nutrition et Santé))[40] differ from IOM guidelines, recommending GWG of 12 kg for women with normal pre-pregnancy BMI, lower GWG (not under 7 kg) for women with overweight or obese pre-pregnancy BMI, and higher GWG for women with underweight pre-pregnancy BMI. However, as French guidelines do not provide upper and lower ranges and IOM guidelines establish clear categories of GWG adequacy, are routinely used in clinical practice and research in other countries, and are better known by French clinicians and therefore likely more widely used in clinical practice, we used the IOM guidelines in our analysis.

Covariates
Maternal characteristics collected by interview prior to hospital discharge used are: pre-pregnancy BMI (defined above; obesity further categorised as obese class I (BMI 30–34.9), II (BMI 35–39.9) and III (BMI ≥40)),[37] parity (primiparous, multiparous), and age (<25, 25–29, 30–34, ≥35 years). Maternal social characteristics included: country/region of birth (France, Europe, Northern Africa, sub-Saharan Africa, other), employment and timing of maternity leave during pregnancy (none;
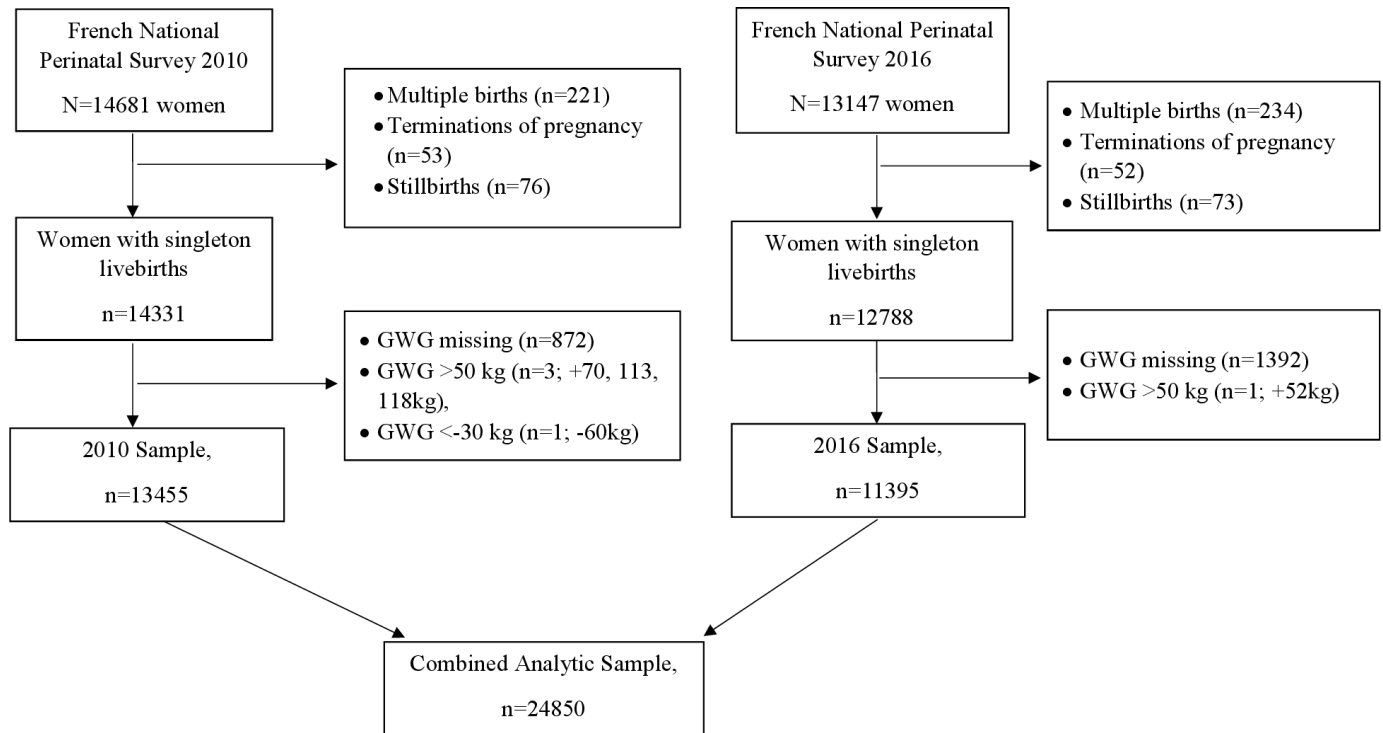
Figure 1 Participant flow chart. GWG, gestational weight gain.

stopped working before 14+0, 28+0, 32+0, at/after 32+0 weeks' gestation, or at an unknown time point), and education (<high school; high school completed; 1–2, 3–4, or 5/more years postgraduation). Smoking was evaluated based on smoking prior to pregnancy versus in the third trimester (for each time point: non-smoker/stopped smoking, <10 cigarettes per day (cig/d), ≥10 cig/d), categorised as: non-smoker at both time points; <10 cig/d, stopped; ≥10 cig/d, stopped; ≥10 cig/d, reduced to <10 cig/d; <10 cig/d, maintained at <10 cig/d; ≥10 cig/d, maintained at ≥10 cig/d; increased smoking (combined

groups of: non-smoker, increased to <10 cig/d; non-smoker, increased to ≥10 cig/d; <10 cig/d, increased to ≥10 cig/d). Social deprivation was based on an index derived within the 2010 NPS based on: receipt of social benefits (household receiving Revenu de Solidarité Active allowance; woman receiving Couverture Maladie Universelle, French social security or not insured), not living in her own accommodation, or not living with a partner.[41] Insufficient prenatal care was defined as late pregnancy declaration (national health insurance not notified in first 3 completed months and no nuchal translucency

Table 1 GWG adequacy determination using a previously described method, based on IOM guidelines, which incorporates gestational age at delivery*

BMI†	IOM recommendations/assumptions for GWG at 40 weeks' gestation			Conversion to proportions of GWG achieved	
	1st trimester GWG (kg)	Rate of GWG (kg/week)	Recommended range (kg)	Expected GWG at 40 weeks	Recommended range of proportion of GWG
Underweight	2	0.51	12.5–18	15.77	0.79–1.14
Normal weight	2	0.42	11.5–16	13.34	0.86–1.20
Overweight	1	0.28	7.0–11.5	8.56	0.81–1.34
Obese	0.5	0.22	5.0–9.0	6.44	0.78–1.41

*Steps to determine GWG adequacy: (1) Expected GWG at 40 weeks computed: recommended first trimester gain+[(GA at birth−13)×recommended rate of GWG]. Example: normal weight BMI: expected GWG=13.34 kg=(2+[40−13]×0.42). (2) Recommended ranges of total GWG for each BMI group converted to ranges of proportions: lower and upper bounds of the IOM recommended range divided by the expected GWG at 40 weeks. Example: normal weight BMI: 0.86–1.20 (11.5/13.34; 16/13.34). (3) For each woman, her individual proportion of recommended GWG achieved determined: observed GWG divided by her expected GWG (using formula from step 1). (4) Individual proportion of recommended GWG achieved compared with ranges of proportions for her BMI group. GWG adequacy classified as: insufficient, below lower bound; adequate, within recommended range; excessive, above upper bound.
†BMI (kg/m²): underweight, <18.5; normal weight, 18.5–24.9; overweight, 25–29.9; obese, ≥30.
BMI, body mass index; GA, gestational age; GWG, gestational weight gain; IOM, Institute of Medicine.

measurement in first trimester) or insufficient sonograms (<2 if gestational age (GA) at birth 24–33 weeks; <3 if GA at birth 34 weeks or later) or prenatal visits (<3 if GA at birth 24–27 weeks; <4 if GA at birth 28–31 weeks; <5 if GA at birth 32–35 weeks; <6 if GA at birth 36 weeks or later), consistent with French guidelines for low-risk women.[42] Pre-pregnancy conditions/pregnancy complications, obtained from chart abstraction and used for descriptive purposes, included diabetes in pregnancy (no; diet controlled; insulin controlled) and pre-existing hypertension.

Statistical analysis

To describe the GWG profile of our cohort, for both survey years combined and individually, mean GWG (with SDs) and prevalence of insufficient, adequate and excessive GWG were reported, overall and by BMI category. The characteristics of included women and women excluded for missing GWG were determined and compared.

Next, the associations between maternal characteristics and GWG and GWG adequacy were evaluated. First, unadjusted linear regression models were used to estimate mean GWG (SD) within levels of maternal characteristics. Then, adjusted linear regression models were used to estimate adjusted mean differences in GWG (and 95% CIs) between categories of maternal characteristics, with a mean GWG difference of >1 kg considered clinically significant. Similarly, adjusted polytomous logistic regression models were used to examine the association between maternal characteristics and GWG adequacy (adjusted OR, 95% CI calculated). Based on covariates previously associated with GWG, adjusted regression models adjusted for all maternal characteristics listed previously as covariates (BMI obesity classes combined), as well as maternal height (metres), GA at birth (days; linear models only, as GA at birth accounted for in definition of GWG adequacy), and survey year. The pre-pregnancy conditions/pregnancy complications (diabetes in pregnancy; pre-existing hypertension) reported in the initial descriptive analysis were not included in the adjusted models because they may be mediators of the association between maternal characteristics and GWG (our primary interest) and could introduce bias if included in the models. To determine whether the associations between obesity classes and GWG and GWG adequacy differed, the adjusted analysis was repeated but with BMI included in the models as a six-level variable (underweight, normal weight, overweight, obese class I, II, and III).

Though GWG differed between survey years, patterns of associations between GWG and maternal characteristics were similar regardless of survey year (data not shown) and we did not make inferences or conclusions about changes in GWG over time. Thus, for analyses of associations between maternal characteristics and GWG, data from the 2010 and 2016 surveys were combined and survey year was included in the models as a covariate rather than stratification variable. Due to the small amounts of missing data for covariates in the analytical sample (<5% of women missing data for any covariate included in the multivariable analyses), multiple imputation was not conducted. Covariates with the highest percentages of missing data were: maternal pre-pregnancy BMI (1%), employment during pregnancy (1%), education (1%), smoking status (1%) and diabetes (1%; not included in multivariable models).

We used SAS software V.9.4 for Windows (SAS Institute) for statistical analyses.

Patient and public involvement

A network representing French user associations on questions related to pregnancy, childbirth and infancy was involved in the development of the questions on pregnancy and birth in the NPS and a website is maintained to disseminate results to participants and the wider public. However, there was no patient or public engagement for this research study.

RESULTS

In our nationally representative sample of French women, women's average GWG was 13.0 kg (SD 5.6; table 2), decreasing from 13.2 kg (SD 5.6) in 2010 to 12.7 kg (SD 5.7) in 2016 (online supplemental table 1). GWG decreased with increasing BMI, including across obesity classes. Only 37.0% of women attained adequate GWG, decreasing slightly from 37.7% in 2010 to 36.2% in 2016. Excessive GWG was more common among women with overweight and obese BMI, while insufficient GWG was more common among women with underweight BMI. However, when examining obesity classes separately, excessive GWG decreased from obese class I to III, while insufficient GWG increased from obese class I to III.

In our cohort (table 3), almost 20% of women were born outside of France, a majority had normal weight BMI entering pregnancy, 30% smoked either before or during pregnancy, 2.0% had pre-existing hypertension and 8.5% had diabetes in pregnancy. Compared with women excluded due to missing or implausible GWG, women included in our analytical sample were more likely to be primiparous, have a lower pre-pregnancy BMI, have modified their smoking habits during pregnancy and have characteristics indicative of higher socioeconomic status (online supplemental table 2).

In unadjusted analysis, clinically significant differences (>1 kg) in mean GWG were found for all maternal characteristics except maternal age and social deprivation (table 3), with higher GWG associated with characteristics indicative of higher socioeconomic status (maternal birth in France or Europe, higher education level, sufficient care) and reduced smoking in pregnancy. For pregnancy complications, mean GWG was lower among women with diabetes during pregnancy (11.1 kg, SD 6.5 among women with insulin controlled and 10.2 kg, SD 7.0 among women with diet controlled diabetes compared to 13.2 kg, SD 5.5 among women without diabetes during pregnancy) or pre-existing hypertension (11.7 kg, SD

Table 2 Nationally representative estimates of GWG and GWG adequacy* in France (French National Perinatal Surveys 2010 and 2016; N=24850)

	n (%)	GWG (kg) mean (SD)	Insufficient GWG n (%)	Adequate GWG n (%)	Excessive GWG n (%)
Overall	24 850	13.0 (5.6)	6606 (26.8)	9106 (37.0)	8892 (36.1)
BMI†					
Underweight	1960 (8.0)	13.9 (4.8)	762 (38.9)	785 (40.1)	411 (21.0)
Normal weight	15 506 (62.9)	13.8 (4.8)	4473 (28.9)	6438 (41.6)	4574 (29.5)
Overweight	4545 (18.4)	12.2 (6.0)	687 (15.1)	1303 (28.7)	2552 (56.2)
All obese	2625 (10.7)	8.6 (7.4)	684 (26.1)	580 (22.1)	1355 (51.7)
Obese class I	1802 (7.3)	9.8 (6.7)	355 (19.8)	392 (21.8)	1050 (58.4)
Obese class II	589 (2.4)	7.0 (7.7)	201 (34.2)	138 (23.5)	249 (42.3)
Obese class III	234 (0.9)	3.6 (8.3)	128 (54.7)	50 (21.4)	56 (23.9)

*Based on 2009 IOM thresholds,[1] accounting for gestational age at birth[38 39]; considered insufficient GWG if below recommendation, adequate if within recommendation or excessive if above recommendation.
†BMI (kg/m^2): underweight, <18.5; normal weight, 18.5–24.9; overweight, 25–29.9; obese, ≥30 (class I (30–34.9); class II (35–39.9); class III (≥40)).[37]
BMI, body mass index; GWG, gestational weight gain; IOM, Institute of Medicine.

7.3 compared to 13.0 kg, SD 5.6 among women without pre-existing hypertension). In adjusted models, clinically significant differences in mean GWG persisted for maternal pre-pregnancy BMI, employment in pregnancy and smoking habits only.

In polytomous logistic regression models (table 4), underweight and obese BMI were positively associated with insufficient GWG. Additional characteristics positively associated with insufficient GWG included birth in sub-Saharan Africa, not being employed in pregnancy, less than high school education and insufficient prenatal care. Conversely, overweight BMI, stopping smoking and primiparity were inversely associated with insufficient GWG.

Overweight and obese pre-pregnancy BMI were positively associated with excessive GWG. Additional characteristics positively associated with excessive GWG included primiparity, not working or stopping work before 28 weeks' gestation, lower education level, and reduced or continued smoking. Conversely, underweight pre-pregnancy BMI was inversely associated with excessive GWG.

When adjusted analyses were repeated to evaluate obesity classes I–III separately (table 5), the trend of greater decreases in GWG compared with women with normal weight BMI persisted. Similarly, the odds of insufficient GWG increased across obesity classes, but the odds of excessive GWG decreased.

DISCUSSION

In France in 2010 and 2016, the majority of women did not achieve recommended GWG based on the 2009 IOM guidelines. Inadequate GWG was associated with underweight, overweight or obese pre-pregnancy BMI, smoking in pregnancy, primiparity and lower socioeconomic status. Differences in the prevalence of insufficient and excessive GWG were also noted by obesity class.

Though the majority of women in our study had inadequate GWG, our results (26.8% insufficient, 36.1% excessive GWG) were similar to those found in recent multinational meta-analyses (LifeCycle (Europe, North America): 21.5% insufficient, 42.0% excessive[43]; Goldstein et al (Europe, USA and Asia): 23% insufficient, 47% excessive).[7] Examining GWG by BMI class, our findings (inverse relationship between pre-pregnancy BMI and mean GWG[1 43–47]; positive association between insufficient GWG and underweight or obese BMI; positive association between excessive GWG and overweight or obese BMI)[15 16 20 36 48–50] were generally consistent with previous studies. Though inadequate GWG is more common among women with underweight, overweight or obese BMI, clinicians providing prenatal care should counsel all women regarding appropriate GWG for their pre-pregnancy BMI. Given the higher risk profile for adverse outcomes and the particular challenges to limit GWG for women entering pregnancy at higher BMI, providing information related to nutrition and physical activity for this group is particularly important.[1] Additionally, as a recent systematic review found that midwives and obstetricians had insufficient knowledge of the IOM recommendations,[51] educating clinicians on guidelines is also vital to ensure evidence-based prenatal counselling for appropriate GWG.

The average GWG (13.8 kg, SD 4.8) of women with normal weight BMI in our cohort exceeded the current French guidelines and mean GWG (with lower,[30] higher[12] and similar estimates)[31] and GWG adequacy (ie, insufficient, adequate or excessive GWG; with varying results depending on BMI category)[12 30 32] in the French population differed between studies. The differences between

Table 3 Distribution of maternal characteristics in the sample and GWG associated with these characteristics (French National Perinatal Surveys 2010 and 2016)

	n (%)	GWG (kg) mean (SD)	Adjusted* difference in GWG (kg) difference (95% CI)
BMI†			
Underweight	1960 (8.0)	13.9 (4.8)	0.0 (−0.3 to 0.3)
Normal weight	15 506 (62.9)	13.8 (4.8)	Reference
Overweight	4545 (18.4)	12.2 (6.0)	**−1.6 (−1.8 to -1.4)**
Obese	2625 (10.7)	8.6 (7.4)	**−5.1 (−5.4 to -4.8)**
Parity			
Multiparous	14 061 (56.7)	12.4 (5.6)	Reference
Primiparous	10 722 (43.3)	13.7 (5.6)	0.7 (0.5 to 0.8)
Age			
<25 years	3716 (15.0)	13.4 (6.3)	−0.0 (−0.3 to 0.2)
25–29 years	8126 (32.7)	13.2 (5.7)	Reference
30–34 years	8079 (32.5)	12.9 (5.4)	0.1 (−0.1 to 0.3)
≥35 years	4918 (19.8)	12.5 (5.5)	−0.0 (−0.3 to 0.2)
Country or region of birth			
France	20 398 (82.2)	13.2 (5.5)	Reference
Europe	957 (3.9)	13.0 (5.7)	0.3 (−0.1 to 0.8)
Northern Africa	1720 (6.9)	12.1 (6.1)	−0.2 (−0.6 to 0.2)
Sub-Saharan Africa	1024 (4.1)	11.2 (6.8)	−0.6 (−1.0 to -0.1)
Other	719 (2.9)	12.5 (5.2)	0.0 (−0.5 to 0.6)
Employment during pregnancy			
None	7089 (28.7)	12.3 (6.4)	0.1 (−0.2 to 0.3)
Stopped working during pregnancy			
Before 14+0 weeks' gestation	1595 (6.5)	13.8 (6.3)	**1.2 (0.8 to 1.5)**
14+0 to 27+6 weeks' gestation	6701 (27.1)	13.5 (5.5)	0.6 (0.4 to 0.9)
28+0 to 31+6 weeks' gestation	4243 (17.2)	13.2 (4.9)	0.3 (−0.0 to 0.5)
Unknown stop point	4743 (19.2)	12.8 (5.6)	0.1 (−0.7 to 0.9)
Continued working to ≥32 weeks' gestation	317 (1.3)	13.0 (4.9)	Reference
Education			
Less than high school	2158 (8.7)	11.9 (6.8)	0.6 (0.2 to 1.0)
High school	9157 (37.1)	13.1 (6.3)	0.8 (0.6 to 1.1)
1–2 years postgraduation	5086 (20.6)	13.2 (5.3)	0.6 (0.4 to 0.9)
3–4 years postgraduation	4466 (18.1)	13.0 (4.9)	0.2 (−0.1 to 0.5)
≥5 years postgraduation	3798 (15.4)	12.9 (4.5)	Reference
Social deprivation‡			
No	20 424 (82.2)	13.1 (5.4)	Reference
Yes	4414 (17.8)	12.5 (6.6)	−0.1 (−0.3 to 0.1)
Smoking habits before, during pregnancy			
Non-smoker	17 216 (69.9)	12.4 (5.3)	Reference
Decreased smoking in pregnancy			
<10 cig/d, stopped	1855 (7.5)	14.4 (5.3)	**1.5 (1.1 to 1.8)**
≥10 cig/d, stopped	1402 (5.7)	16.2 (5.9)	**3.3 (2.9 to 3.7)**
≥10 cig/d, <10 cig/d	2185 (8.9)	14.0 (6.2)	**1.3 (0.9 to 1.6)**
Maintained smoking level in pregnancy			

Continued

Table 3   Continued

	n (%)	GWG (kg) mean (SD)	Adjusted* difference in GWG (kg) difference (95% CI)
<10 cig/d, <10 cig/d	845 (3.4)	13.4 (6.4)	0.9 (0.4 to 1.4)
≥10 cig/d, >10 cig/d	1081 (4.4)	12.4 (6.5)	0.1 (−0.4 to 0.5)
Increased smoking in pregnancy§	47 (0.2)	13.6 (5.4)	1.1 (−0.9 to 3.2)
Insufficient care¶			
No	23 515 (94.7)	13.1 (5.6)	Reference
Yes	1328 (5.3)	11.5 (6.4)	−0.9 (−1.2 to −0.6)

Bold: clinically (>1 kg) and statistically significant mean difference.
*Estimated using adjusted linear regression models; adjusted on all covariates in table, survey year, GA at birth and mother's height.
†BMI (kg/m^2): underweight, <18.5; normal weight, 18.5–24.9; overweight, 25–29.9; obese, ≥30.[37]
‡Receipt of social benefits, not living in her own accommodation, not living with a partner
§Non-smoker, <10 cig/d; non-smoker, ≥10 cig/d; <10 cig/d, ≥10 cig/d.
¶Late pregnancy declaration (national health insurance not notified in first 3 completed months and no nuchal translucency measurement in first trimester) or insufficient sonograms (<2 if GA at birth 24–33 weeks; <3 if GA at birth 34 weeks or later) or prenatal visits (<3 if GA at birth 24–27 weeks; <4 if GA at birth 28–31 weeks; <5 if GA at birth 32–35 weeks; <6 if GA at birth 36 weeks or later), consistent with French guidelines for low-risk women.
BMI, body mass index; cig/d, cigarettes per day; GA, gestational age; GWG, gestational weight gain.

the French study results may be attributed to differences in study design (retrospective vs prospective; nationally representative vs limited/local hospital-based), location, GWG classification method (accounting for GA at birth or not), and inclusion/exclusion criteria (women with pre-existing conditions excluded or not). While our study is the first in France to provide nationally representative estimates of GWG and GWG adequacy, additional research within nationally representative samples of the French population is necessary to define adequate GWG in relation to adverse outcomes and clarify national guidelines.

Due to the lack of evidence to determine whether separate guidelines may be necessary in women with obese pre-pregnancy BMI,[14] we extended our analyses to compare mean GWG and GWG adequacy between obesity classes. Our results are consistent with previous studies conducted in Europe, North America and Reunion Island, finding insufficient GWG increased and excessive GWG decreased from obesity class I to III[20 52 53] and supporting evidence that lower GWG guidelines may be appropriate for higher obesity.[43 52 54 55] Future research should address uncertainties regarding GWG guidelines for different obesity classes.

In line with previous research conducted in North America, Brazil, Australia, New Zealand and Ireland, we also found increased absolute GWG[22 23 56] and increased excessive GWG[15 20 22 56] among women who quit smoking in pregnancy, likely due to physiological changes to the metabolism and central nervous system resulting in increased appetite and the behavioural substitution of cigarettes with consumption of sugary foods.[57] Given the obvious benefits of quitting smoking before or during pregnancy due to the adverse effects of smoking (eg, reduced fetal growth and birth size),[58 59] smokers should be encouraged to reduce/stop smoking during pregnancy,

be provided additional nutritional and psychological support to avoid adverse effects of excessive GWG, and be educated on the use of nicotine-replacement therapies (eg, nicotine patches).

Finally, we found that a number of maternal and social characteristics were associated with inadequate GWG, though consistency with prior literature was mixed. While we found increased GWG in primiparas compared with multiparas, a recent multinational systematic review concluded that the evidence is inconsistent and that the role of parity on GWG is likely indirect and complex.[60] Overall, our results suggest that French women of lower socioeconomic status are more likely to have inadequate GWG, though the evidence for these factors is inconsistent. In contrast to our results, studies from Australia, New Zealand, Ireland, Brazil and the USA have found increased excessive GWG with younger maternal age.[15 19 49 50] Results for education have been mixed, with some previous studies from North American and Australia also finding lower education was associated with insufficient/[5 17 50]low[8] or excessive weight gain[5 17 49] but others from the USA and the Netherlands finding that the associations between education and GWG differed by maternal BMI[20 25] or no differences.[18] Conflicting results have also been found related to immigration, with some previous research reporting higher GWG and increased excessive GWG in foreign nationals in Ireland[27] or recent immigrants in Australia, New Zealand and Ireland[15] but others finding insufficient GWG increased among foreign-born women in the USA[16] or excessive GWG decreased among women of non-European ancestry living in the Netherlands,[18] similar to our finding of increased insufficient GWG among women born in sub-Saharan Africa. In contrast, insufficient prenatal care was associated with insufficient GWG consistently across studies in the USA and Romania,[16 21 24] in line with our results. Given the

Table 4 Associations between maternal characteristics and insufficient or excessive GWG* in multivariable logistic regression models (French National Perinatal Surveys 2010 and 2016; N=23931)

	Insufficient GWG aOR† (95% CI)	Excessive GWG aOR† (95% CI)
BMI‡		
Underweight	**1.4 (1.2 to 1.5)**	**0.7 (0.6 to 0.8)**
Normal weight	Reference	Reference
Overweight	**0.7 (0.6 to 0.8)**	**2.8 (2.6 to 3.1)**
Obese	**1.5 (1.4 to 1.7)**	**3.3 (2.9 to 3.6)**
Primiparity (vs multiparous)	**0.9 (0.9 to 1.0)**	**1.2 (1.2 to 1.3)**
Age		
<25 years	1.1 (1.0 to 1.2)	1.0 (0.9 to 1.1)
25–29 years	Reference	Reference
30–34 years	1.0 (0.9 to 1.1)	1.0 (0.9 to 1.1)
≥35 years	1.0 (0.9 to 1.1)	0.9 (0.9 to 1.0)
Country or region of birth (vs France)		
Europe	0.9 (0.8 to 1.1)	1.1 (0.9 to 1.3)
Northern Africa	1.1 (1.0 to 1.3)	1.1 (1.0 to 1.3)
Sub-Saharan Africa	**1.2 (1.0 to 1.5)**	1.1 (0.9 to 1.3)
Other	1.0 (0.8 to 1.2)	1.1 (0.9 to 1.3)
Employment during pregnancy		
None	**1.2 (1.0 to 1.3)**	**1.2 (1.1 to 1.3)**
Stopped working during pregnancy		
Before 14+0 weeks' gestation	1.0 (0.8 to 1.1)	**1.6 (1.4 to 1.8)**
14+0 to 27+6 weeks' gestation	0.9 (0.8 to 1.0)	**1.2 (1.1 to 1.4)**
28+0 to 31+6 weeks' gestation	0.9 (0.8 to 1.0)	1.1 (1.0 to 1.2)
Unknown stop point	1.1 (0.8 to 1.4)	1.0 (0.8 to 1.4)
Continued working to ≥32 weeks' gestation	Reference	Reference
Education (vs ≥5 years postgraduation)		
Less than high school	**1.2 (1.0 to 1.4)**	**1.5 (1.3 to 1.7)**
High school	1.0 (0.9 to 1.1)	**1.5 (1.3 to 1.6)**
1–2 years postgraduation	0.9 (0.8 to 1.0)	**1.3 (1.2 to 1.5)**
3–4 years postgraduation	1.0 (0.9 to 1.1)	1.1 (1.0 to 1.2)
Social deprivation§	1.1 (1.0 to 1.2)	1.0 (0.9 to 1.1)
Smoking habits before, during pregnancy (vs non-smokers)		
Decreased smoking in pregnancy		
<10 cig/d, stopped	**0.7 (0.6 to 0.8)**	**1.4 (1.3 to 1.6)**
≥10 cig/d, stopped	**0.6 (0.5 to 0.7)**	**2.6 (2.3 to 2.9)**
≥10 cig/d, <10 cig/d	0.9 (0.8 to 1.0)	**1.5 (1.4 to 1.7)**
Maintained smoking level in pregnancy		
<10 cig/d, <10 cig/d	1.1 (0.9 to 1.3)	**1.5 (1.3 to 1.8)**

Continued

Table 4 Continued

	Insufficient GWG aOR† (95% CI)	Excessive GWG aOR† (95% CI)
≥10 cig/d, >10 cig/d	1.2 (1.0 to 1.4)	**1.2 (1.0 to 1.4)**
Increased smoking in pregnancy¶	0.7 (0.3 to 1.5)	1.4 (0.7 to 2.7)
Insufficient care**	**1.2 (1.1 to 1.4)**	0.9 (0.7 to 1.0)

Bold: statistically significant association (does not cross null).
*Based on 2009 IOM thresholds,[1] accounting for GA at birth[38 39]; considered insufficient GWG if below recommendation, adequate if within recommendation or excessive if above recommendation.
†Estimated using polytomous logistic regression models; adjusted on all covariates in table, survey year and mother's height.
‡BMI (kg/m^2): underweight, <18.5; normal weight, 18.5–24.9; overweight, 25–29.9; obese, ≥30.[37]
§Receipt of social benefits, not living in her own accommodation, not living with a partner
¶Non-smoker, <10 cig/d; non-smoker, ≥10 cig/d; <10 cig/d, ≥10 cig/d.
**Late pregnancy declaration (national health insurance not notified in first 3 completed months and no nuchal translucency measurement in first trimester) or insufficient sonograms (<2 if GA at birth 24–33 weeks;<3 if GA at birth 34 weeks or later) or prenatal visits (<3 if GA at birth 24–27 weeks; <4 if GA at birth 28–31 weeks; <5 if GA at birth 32–35 weeks; <6 if GA at birth 36 weeks or later), consistent with French guidelines for low-risk women.
aOR, adjusted OR; BMI, body mass index; cig/d, cigarettes per day; GA, gestational age; GWG, gestational weight gain; IOM, Institute of Medicine.

disparate results across study settings, a deeper understanding of the underlying cultural context and social conditions is important to develop specific strategies to improve care for vulnerable populations and ensure all women, in particular those of lower socioeconomic status, can achieve a nutritionally adequate diet.

With its comprehensive analysis of factors contributing to GWG within a large, contemporary, nationally representative French cohort, our study builds on prior literature. As previous French GWG studies investigated different research questions,[12 30–32] we provide evidence of risk factors in a unique setting which could inform interventions locally and future research related to mechanisms underlying the observed associations. Additional strengths of our study include the extensive, rigorous data obtained in the NPSs by specially trained study personnel, which previous studies have confirmed are nationally representative based on comparisons of selected perinatal indicators (eg, maternal age, GA) available from birth certificate and hospital discharge statistics in the corresponding years.[28 29] By accounting for GA at birth in our definition of GWG adequacy and controlling for GA at birth in linear models of GWG, we limited potential biases due to the inherent correlation between GWG and length of gestation.[61 62] Additionally, our population included few preterm births (5.3%) and preliminary sensitivity analyses of term pregnancies within our

Table 5 Association between maternal pre-pregnancy BMI* and GWG and GWG adequacy,† accounting for obesity classes I–III in adjusted regression models‡ (French National Perinatal Surveys 2010 and 2016)

	N	GWG (kg) mean (SD)	Adjusted difference in GWG (kg) difference (95% CI)	Insufficient GWG aOR† (95% CI)	Excessive GWG aOR† (95% CI)
Underweight	1960	13.9 (4.8)	0.0 (−0.3 to 0.3)	**1.4 (1.2 to 1.5)**	**0.7 (0.6 to 0.8)**
Normal weight	15 506	13.8 (4.8)	Reference	Reference	Reference
Overweight	4545	12.2 (6.0)	**−1.6 (−1.8 to -1.4)**	**0.7 (0.6 to 0.8)**	**2.8 (2.6 to 3.1)**
Obese class I	1802	9.8 (6.7)	**−3.9 (−4.3 to -3.6)**	**1.2 (1.0 to 1.4)**	**3.8 (3.4 to 4.3)**
Obese class II	589	7.0 (7.7)	**−6.7 (−7.3 to -6.2)**	**1.9 (1.5 to 2.4)**	**2.4 (2.0 to 3.0)**
Obese class III	234	3.6 (8.3)	**−10.2 (−11.1 to -9.3)**	**3.4 (2.4 to 4.7)**	1.3 (0.9 to 2.0)

BOLD: for adjusted differences, clinically (>1 kg) and statistically significant mean difference; for aORs, statistically significant association (does not cross null).

*BMI (kg/m²): underweight, <18.5; normal weight, 18.5–24.9; overweight, 25–29.9; obese class I, 30–34.9; obese class II, 35–39.9; obese class III, ≥40.[37]

†Based on 2009 IOM thresholds,[1] accounting for GA at birth[38,39]; considered insufficient GWG if below recommendation, adequate if within recommendation or excessive if above recommendation.

‡Linear regression used to estimated differences and polytomous logistic regression used to estimated aORs; adjustment variables: parity, maternal age, maternal country/region of birth, employment during pregnancy, education, social deprivation, smoking habits, insufficient care, survey year, mother's height (all models) and GA at birth (linear models only).

aOR, adjusted OR; BMI, body mass index; GA, gestational age; GWG, gestational weight gain; IOM, Institute of Medicine.

cohort were consistent with our main analyses (data not reported), providing further evidence that biases due to GA at birth were minimised. Additional methodological strengths are the large sample size and low level of missing data (<5% in multivariable analyses).

Our study has some limitations. Measurement error is possible as some data were self-reported and collected retrospectively. Specifically, self-reported pre-pregnancy weight and maternal weight at birth may be biased due to underestimation.[63] However, because reporting of weight gain during pregnancy in medical records is not standardised across France, the NPSs obtain this information through maternal self-report in order to have consistently collected and more complete data. While the resulting bias due to misclassification in measuring associations between GWG and adverse outcomes may be minimal, the impact of misclassification in examining risk factors for weight outcomes has not been evaluated.[63] Only total GWG, not longitudinal GWG, was collected, reducing precision[64] and not allowing us to examine variations in GWG trajectory across pregnancy or timing of GWG. GWG data in the NPSs used for our analysis were available for more than 90% of women and less than 5% of included women had missing data for covariates in our analysis. However, because differences were noted between included and excluded women, with excluded women being more likely to have characteristics indicative of lower socioeconomic status, we may have underestimated the association between these characteristics and GWG.

CONCLUSIONS

In France, a minority of women achieves the IOM-recommended GWG. Maternal pre-pregnancy BMI, continuing or quitting smoking in pregnancy, and lower socioeconomic status were associated with not achieving GWG recommendations. To promote adequate GWG and optimise pregnancy outcomes, clinicians should be trained to ensure all pregnant women receive evidence-based advice related to GWG and to provide additional support tailored to the specific needs of at-risk groups. Given the uncertainties regarding the current IOM GWG recommendations, additional research within nationally representative samples outside the USA and within BMI obesity classes is needed.

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eTable 1. Nationally-representative estimates of GWG and GWG adequacy[a] in France by survey year (French National Perinatal Survey 2010 and 2016; N=24850)

	2010					2016				
	N (%)	GWG (kg) mean (SD)	Insufficient GWG n (%)	Adequate GWG n (%)	Excessive GWG n (%)	N (%)	GWG (kg) mean (SD)	Insufficient GWG n (%)	Adequate GWG n (%)	Excessive GWG n (%)
Total	13455	13.2 (5.6)	3443 (25.9)	5006 (37.7)	4839 (36.4)	11395	12.7 (5.7)	3163 (28.0)	4100 (36.2)	4053 (35.8)
BMI[b]										
Underweight	1110 (8.3)	14.0 (4.7)	415 (37.5)	454 (41.0)	239 (21.6)	850 (7.5)	13.7 (4.9)	347 (40.8)	331 (38.9)	172 (20.2)
Normal weight	8601 (64.7)	13.9 (4.8)	2394 (27.9)	3614 (42.1)	2583 (30.1)	6905 (60.9)	13.7 (4.9)	2079 (30.2)	2824 (41.0)	1991 (28.9)
Overweight	2289 (17.2)	12.4 (5.9)	310 (13.6)	662 (28.9)	1315 (57.5)	2256 (19.9)	12.0 (6.0)	377 (16.7)	641 (28.4)	1237 (54.9)
All obese	1303 (9.8)	8.9 (7.4)	324 (24.9)	276 (21.2)	702 (53.9)	1322 (11.7)	8.4 (7.3)	360 (27.3)	304 (23.1)	653 (49.6)
Obese class I	893 (6.7)	10.2 (6.7)	162 (18.2)	190 (21.3)	540 (60.5)	909 (8.0)	9.5 (6.7)	193 (21.3)	202 (22.3)	510 (56.4)
Obese class II	280 (2.1)	7.0 (8.0)	92 (32.9)	64 (22.9)	124 (44.3)	309 (2.7)	7.0 (7.4)	109 (35.4)	74 (24.0)	125 (40.6)
Obese class III	130 (1.0)	4.2 (8.1)	70 (53.8)	22 (16.9)	38 (29.2)	104 (0.9)	2.8 (8.6)	58 (55.8)	28 (26.9)	18 (17.3)

Abbreviations: GWG= gestational weight gain; BMI= body mass index; SD= standard deviation; IOM= Institute of Medicine

[a]Based on 2009 IOM thresholds,[1] accounting for gestational age at birth;[2,3] considered insufficient GWG if below recommendation, adequate if within recommendation, or excessive if above recommendation

[b]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30 (class I [30-34.9]; class II [35-39.9]; class III [$\geq$40])[4]

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eTable 2: Characteristics of the study population, in comparison to those of women excluded for missing or implausible GWG (French National Perinatal Survey 2010 and 2016)

	Included (N=24850) n (%)	Excluded (N=2269) n (%)
BMI[a]		
Underweight	1960 (8.0)	7 (4.2)
Normal weight	15506 (62.9)	92 (55.1)
Overweight	4545 (18.4)	33 (19.8)
All obese	2625 (10.7)	35 (21.0)
Obese class I	1802 (7.3)	25 (15.0)
Obese class II	589 (2.4)	7 (4.2)
Obese class III	234 (0.9)	3 (1.8)
Parity		
Multiparous	14061 (56.7)	1100 (63.5)
Primiparous	10722 (43.3)	632 (36.5)
Age		
<25 years	3716 (15.0)	370 (22.0)
25-29 years	8126 (32.7)	482 (28.6)
30-34 years	8079 (32.5)	476 (28.3)
≥35 years	4918 (19.8)	356 (21.1)
Country or region of birth		
France	20398 (82.2)	280 (53.6)
Europe	957 (3.9)	47 (9.0)
Northern Africa	1720 (6.9)	63 (12.1)
Sub-Saharan Africa	1024 (4.1)	101 (19.3)
Other	719 (2.9)	31 (5.9)
Employment during pregnancy		
None	7089 (28.7)	404 (60.3)
Stopped working during pregnancy		
Before 14+0 wks gestation	1595 (6.5)	20 (3.0)
14+0 to 27+6 wks gestation	6701 (27.1)	58 (8.7)
28+0 to 31+6 wks gestation	4243 (17.2)	24 (3.6)
Unknown stop point	317 (1.3)	124 (18.5)
Continued working to ≥32 wks gestation	4743 (19.2)	40 (6.0)
Education		
Less than high school	2158 (8.7)	217 (37.0)
High school	9157 (37.1)	226 (38.5)
1-2 years post-graduation	5086 (20.6)	67 (11.4)
3-4 years post-graduation	4466 (18.1)	50 (8.5)
≥5 years post-graduation	3798 (15.4)	27 (4.6)
Social deprivation[b]		
No	20424 (82.2)	304 (60.9)
Yes	4414 (17.8)	195 (39.1)
Smoking habits before, during pregnancy		
Non smoker	17216 (69.9)	297 (72.1)
Decreased smoking in pregnancy		
<10 cig/d, stopped	1855 (7.5)	18 (4.4)
≥10 cig/d, stopped	1402 (5.7)	17 (4.1)
≥10 cig/d, <10 cig/d	2185 (8.9)	21 (5.1)
Maintained smoking level in pregnancy		
<10 cig/d, <10 cig/d	845 (3.4)	32 (7.8)
≥10 cig/d, ≥10 cig/d	1081 (4.4)	26 (6.3)
Increased smoking in pregnancy[c]	47 (0.2)	1 (0.2)
Insufficient care[d]		
No	23515 (94.7)	673 (83.3)
Yes	1328 (5.3)	135 (16.7)
Diabetes		
No	22414 (91.5)	1490 (89.4)
Yes, diet controlled	633 (2.6)	42 (2.5)
Yes, insulin controlled	1458 (5.9)	134 (8.0)
Preexisting hypertension		
No	24229 (98.0)	1656 (97.5)
Yes	504 (2.0)	42 (2.5)

Abbreviations: GWG= gestational weight gain; BMI= body mass index; cig/d= cigarettes per day; GA= gestational age

[a]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30 (class I [30-34.9]; class II [35-39.9]; class III [≥40])[4]

[b]No stable home (homeless or living in a hotel or caravan) and/or no salary nor unemployment allowance

[c]Non-smoker, <10 cig/d; non-smoker, ≥10 cig/d; <10 cig/d, ≥10 cig/d

[d]Late pregnancy declaration (national health insurance not notified in first three completed months and no nuchal translucency measurement in first trimester) or insufficient sonograms (<2 if GA at birth 24-33 weeks; <3 if GA at birth 34 weeks or later) or prenatal visits (<3 if GA at birth 24-27 weeks; <4 if GA at birth 28-31 weeks; <5 if GA at birth 32-35 weeks; <6 if GA at birth 36 weeks or later), consistent with French guidelines for low risk women

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