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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 GWG adequacy and identify maternal characteristics associated with insufficient or excessive GWG in France.

Design: French National Perinatal Survey 2010 and 2016, a population-based, nationally representative study

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 prepregnancy weight (kg) and categorized as "insufficient", "adequate", or "excessive" using 2009 Institute of Medicine thresholds. Classification accounted for prepregnancy body mass index (kg/m^2; underweight [<18.5], normal weight [18.5-24.9], overweight [25-29.9], obese [≥30]) and gestational age at delivery. 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 (standard deviation 5.6) kg, with 26.8% of women gaining insufficiently and 36.1% excessively. Among other factors, insufficient GWG was associated with underweight (versus normal weight; adjusted OR [aOR] 1.4, 95%CI 1.2, 1.5) and obese (aOR 1.5, 95%CI 1.4, 1.7) BMI. Excessive GWG was associated with overweight (aOR 2.8, 95%CI 2.6, 3.1) and obese BMI (aOR 3.3, 95%CI 2.9, 3.6). Additionally, excessive GWG was associated with decreased or stopped smoking compared to no smoking, with stronger associations with greater decreases (≥10 cigarettes/day, stopped: aOR 2.6, 95%CI 2.3, 2.9; aORs 1.4-1.5 for lesser decreases). Additional characteristics associated with excessive GWG included primiparity (aOR 1.2, 95%CI 1.2, 1.3), lower education level (aORs 1.1-1.5), and not

working/stopping working earlier in pregnancy (versus working until 32+0 weeks gestation or later: aORs 1.1-1.6).

Conclusions: In France, insufficient and excessive GWG are common. For optimal outcomes, support is needed for women with characteristics associated with insufficient and excessive GWG, including nutritional advice for women quitting smoking or with high or low BMI.

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 (NPS) 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 prepregnancy BMI and GWG) was self-reported and collected retrospectively, which could result in measurement error

Introduction

Due to demographic and lifestyle changes, women are entering pregnancy with higher body mass index (BMI) and gaining excessive pregnancy weight,[1-4] concerning trends as adequate gestational weight gain (GWG) is important for optimal fetal growth and pregnancy/birth outcomes. Specifically, excessive GWG is associated with cesarean delivery,[5,6] postpartum weight retention/obesity,[7,8] increased infant size[6,9] and childhood overweight/obesity.[10,11] Conversely, insufficient GWG is associated with decreased infant size[6,9,12] and preterm birth.[6] In 2009, the United States' Institute of Medicine (IOM; now National Academy of Medicine), updated its GWG guidelines[1] which are stratified by prepregnancy BMI, considered simultaneously a risk factor GWG, an independent risk factor for adverse perinatal outcomes, and a modifier of associations between GWG and several adverse outcomes[1,8,13] (e.g., the association between GWG and postpartum weight retention was strongest among underweight women).[8]

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 prepregnancy BMI, numerous maternal factors, including socio-demographic characteristics, are potentially associated with GWG.[7,14-26] However, evidence gaps exist, as these studies of GWG risk factors were largely conducted in the United States,[7,15,16,19,21,23,24] with further evidence needed in diverse populations,[1] and are not nationally-representative. Further, many had a relatively small sample size (N<1,000),[18,21,22,25,26] used GWG guidelines[7,15,16,18,21] or data collected prior to the 2009 IOM guidelines,[14,17,24] or focused narrowly on specific risk factors.[21-25]

In France, BMI and inadequate GWG prevalence are increasing.[3,27,28] While previous French GWG studies evaluated adverse outcomes of GWG[11,29-31] or reported overviews of the main pregnancy indicators,[27,28] no study has comprehensively assessed GWG risk factors in France. Thus, factors previously identified may not be relevant in France, which compared to the United States, has lower BMI and GWG, higher rates of smoking, and stronger social security and public healthcare systems. To build upon 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 organizational settings, our objectives were to provide population-based estimates of average GWG and the proportion 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

We combined data from the 2010[28] and 2016[27] French National Perinatal Surveys (NPSs), 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) during 1 week (all births every other day over a 2-week period for maternity units with >2000 births/year). Data collection, performed by trained study midwives, includes a face-to-face interview of women prior to hospital discharge (2-3 days following delivery) using a standardized 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 >50kg or loss >30kg[8,32] (n=4 in 2010; n=1 in 2016). Based on missing/implausible GWG, <10% of women with singleton livebirths in the NPS were excluded. Our final analysis included 24,850 women (n=13,455 in 2010; n=11,395 in 2016; Figure 1).

Observed GWG (kg) was calculated based on women's self-reported end of pregnancy minus prepregnancy weight. Then, as described previously,[33,34] *GWG adequacy*, accounting for gestational age (GA) at delivery, was determined by maternal prepregnancy BMI (kg/m^2; using self-reported height and prepregnancy weight; underweight [<18.5], normal weight [18.5-24.9], overweight [25-29.9], obese [≥30]),[35] based on the 2009 IOM guidelines assumptions. To compute *expected GWG*, the following formula was used:

Expected GWG = recommended first trimester gain + [(GA at delivery – 13)*recommended rate of GWG per week in second and third trimesters]

Thresholds by prepregnancy BMI for 1st trimester GWG are: 2 kg (underweight, normal), 1 kg (overweight), and 0.5 kg (obese), and for rates of GWG per week: 0.51 kg/week (underweight), 0.42 kg/week (normal), 0.28 kg/week (overweight), and 0.22 kg/week (obese BMI).[34] For example, a woman with normal weight BMI and GA at delivery of 40 weeks would have an expected GWG of 13.34kg (2+[40-13]*0.42).

To standardize published IOM recommended ranges of GWG for 40 weeks gestation across all GAs, each woman's *proportion of recommended GWG achieved* (*observed* divided by *expected GWG*) was utilized. To derive ranges for *proportion of recommended GWG*

achieved, for each BMI group, lower and upper bounds of the range provided by IOM for 40 weeks gestation were divided by the *expected GWG* at 40 weeks. For example, the recommended range of GWG for a woman with normal weight BMI is 11.5-16kg, which based on the *expected GWG* of 13.34kg (calculated above) corresponds to *proportions of recommended GWG achieved* of 0.86-1.20 (11.5/13.34; 16/13.34). Based on the *proportions of recommended GWG achieved* specific to each BMI group as calculated based on recommendations for 40 weeks and considered constant across GAs, *GWG adequacy* was classified as (per range of proportions): *insufficient* (below lower bound), *adequate* (within recommended range), or *excessive GWG* (above upper bound).

French guidelines for GWG (2007 French National Nutrition and Health Program [Programme National Nutrition et Santé])[36] differ from IOM guidelines, recommending GWG of 12kg for women with normal prepregnancy BMI, lower GWG (not under 7kg) for women with overweight or obese prepregnancy BMI, and higher GWG for women with underweight prepregnancy BMI. However, as French guidelines do not provide upper and lower ranges and IOM guidelines establish clear categories of GWG adequacy and are routinely used in clinical practice and research in other countries, we used the IOM guidelines in our analysis.

Maternal characteristics collected by interview prior to hospital discharge utilized are: prepregnancy BMI (defined above; obesity further categorized as obese class I [BMI 30-34.9], II [BMI 35-39.9], and III [BMI≥40]),[35] 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; 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 post-graduation). Smoking was evaluated based on

smoking prior to pregnancy versus in the 3rd trimester (for each time point: non-smoker/stopped smoking, <10 cigarettes per day [cig/d], ≥10cig/d), categorized as: non-smoker at both time points; <10cig/d, stopped; ≥10cig/d, stopped; ≥10cig/d, reduced to <10cig/d; <10cig/d, maintained at <10cig/d; ≥10cig/d, maintained at ≥10cig/d; increased smoking [combined groups of: non-smoker, increased to <10cig/d; non-smoker, increased to ≥10cig/d; <10cig/d, increased to ≥10cig/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.[37] Insufficient prenatal care was defined as late pregnancy declaration or insufficient sonograms or prenatal visits based on GA at delivery. Prepregnancy conditions/pregnancy complications, obtained from chart abstraction and used for descriptive purposes, included diabetes in pregnancy (no; diet controlled; insulin controlled) and preexisting hypertension.

Statistical analysis

Mean GWG and the proportion of women in each GWG adequacy category, overall and by BMI category and parity, were estimated, by survey year and overall. The characteristics of included women and women excluded for missing GWG were determined. To determine factors associated with GWG, linear regression models were used to estimate unadjusted GWG within and adjusted differences in GWG between categories of maternal characteristics. Based on covariates previously associated with GWG, multivariable models adjusted for all maternal characteristics listed (BMI obesity classes combined), and additionally adjusted for maternal height (meters), GA at delivery (days), and survey year. A mean GWG difference of >1kg was considered clinically significant. Prepregnancy conditions/pregnancy complications were not included in adjusted models as our primary

interest was identifying social factors and because diabetes and hypertension may be mediators of the association between maternal characteristics and GWG. Polytomous logistic regression models, adjusted on the same covariates (except GA at delivery, which was accounted for in of the GWG adequacy definition), were used to examine the association between maternal characteristics and GWG adequacy.

For descriptive analyses of GWG and GWG adequacy, means and standard deviations (SDs) or percentages are reported, as appropriate. For comparative analyses, appropriate measures of association (adjusted mean difference or odds ratio [aOR]) and 95% confidence intervals (CIs) are reported. 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 analytic 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 prepregnancy BMI (1%), employment during pregnancy (1%), education (1%), smoking status (1%), and diabetes (1%; not included in multivariable models).

We used SAS software version 9.4 for Windows (SAS Institute Inc., Cary, NC) for statistical analyses.

Patient and public involvement

A network representing French user associations on questions related to pregnancy, childbirth and infancy were 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, 29.1% were overweight or obese (respectively 18.4%, 10.7%), entering pregnancy, increasing from 27.0% in 2010 to 31.6% in 2016. Overall, women's average GWG was 13.0kg (SD 5.6), decreasing from 13.2kg (SD 5.6) in 2010 to 12.7kg (SD 5.7) in 2016. GWG decreased with increasing BMI and though primiparas weighed less prepregnancy (62.7kg, SD 13.2 versus 65.0kg, SD 14.1), they gained more (13.7kg, SD 5.6 versus 12.4kg, SD 5.6) than multiparas. 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 overweight (56.2%) and obese women (51.7%), while insufficient GWG was more common among women with underweight (38.9%) or obese class III BMI (54.7%). Primiparas (38.8%) were slightly more likely to gain excessively than multiparas (34.2%), but slightly less likely to gain insufficiently (24.6% versus 28.6%, respectively; Table 1; eTable 1).

Table 2 describes the maternal socio-economic characteristics of the sample, average GWG within each group, and differences in GWG between groups. Almost 20% of women in our sample were born outside of France, 17.8% were socially deprived, 30% smoked before or during pregnancy, and 5.3% had insufficient prenatal care. In unadjusted analysis, clinically significant differences (>1kg) in mean GWG were found for all maternal characteristics except social deprivation and maternal age. In adjusted models, clinically significant decreases in GWG were noted as BMI increased (compared to women with normal prepregnancy BMI), whereas clinically significant increases in GWG were noted among

women quitting or reducing smoking (compared to non-smokers) and women who stopped working before 14 weeks gestation (compared to women continuing working until at least 32 weeks). Compared to women excluded due to missing or implausible GWG, women included in our analytic sample were more likely to be primiparous, have a lower prepregnancy BMI, have modified their smoking habits during pregnancy, and have characteristics indicative of higher socio-economic status (eTable 2).

In polytomous logistic regression models (Table 3), underweight (aOR 1.4, 95% CI 1.2, 1.5) and obese BMI (increasing by class; class I: aOR 1.2; 95% CI 1.0, 1.4; class II: aOR 1.9, 95% CI 1.5, 2.4; class III: aOR 3.4, 95% CI 2.4, 4.7) were associated with increased odds of insufficient GWG. Additionally, maternal social characteristics associated with increased odds of insufficient GWG included birth in Northern or sub-Saharan Africa, not being employed in pregnancy, less than high school education, and insufficient prenatal care. Conversely, overweight BMI (aOR 0.69, 95% CI 0.62, 0.77) and stopped or reduced smoking (aORs ranging from 0.66-0.90 depending on levels of smoking and reduction) were associated with decreased odds insufficient GWG. Additional characteristics associated with decreased odds of insufficient GWG included primiparity, stopping work between 14+0 and 31+6 weeks gestation, and education of 1-2 years post-graduation.

Maternal characteristics associated with increased odds of excessive GWG were overweight (aOR 2.8, 95% CI 2.6, 3.1) or obese prepregnancy BMI (decreasing by class; class I: aOR 3.8, 95% CI 3.4, 4.3; class II: aOR 2.4, 95% CI 2.0, 3.0; class III aOR 1.3, 95% CI 0.90, 2.0) and reduced or continued/increased smoking (aORs ranging from 1.2 to 2.6 depending on levels of smoking and reduction). Additional characteristics associated with excessive GWG included primiparity, not working or stopping work before 32 weeks gestation, and lower education level. Conversely, underweight prepregnancy BMI (aOR 0.67, 95% CI 0.59, 0.76)

was protective against excessive GWG. Additional characteristics associated with excessive GWG included maternal age over 35 years and insufficient prenatal care.

Discussion

In France in 2010 and 2016, the majority of women did not achieve adequate GWG based on the 2009 IOM guidelines. Insufficient GWG was associated with underweight or obese prepregnancy BMI; excessive GWG was associated with overweight or obese prepregnancy BMI and reducing/quitting smoking. Additionally, many social factors (education, working during pregnancy, insufficient prenatal care, maternal birth location) were associated with either insufficient or excessive GWG.

The NPSs provide extensive, rigorous data obtained by specially trained study personnel on maternal socio-demographic characteristics and behavioral factors obtained through interview as well as health and delivery information obtained through chart abstraction. Previous studies have confirmed that the NPSs are nationally representative based on comparisons of selected perinatal indicators (e.g., maternal age, GA) available from birth certificate and hospital discharge statistics in the corresponding years.[27,28] By accounting for GA at delivery in our definition of GWG adequacy and controlling for GA at delivery in linear models of GWG, we limited potential biases due to the inherent correlation between GWG and length of gestation.[38,39] Additionally, our population included few preterm deliveries (5.3%) and preliminary sensitivity analyses of term pregnancies within our cohort were consistent with our main analyses (data not reported), providing further evidence that biases due to GA at delivery were minimized. Additional methodological strengths are the large sample size and low level of missing data (<5% in multivariable analyses).

With its comprehensive analysis of factors contributing to GWG within a large, contemporary, nationally-representative French cohort, our study builds upon prior literature. As previous French studies focused on other aspects of GWG,[11,29-31] the unique study location permits the comparison of risk factors across different settings, providing insight into underlying mechanisms and their amenability to intervention, generating hypotheses regarding biologic versus environmental/social etiology, and informing public health policies and interventions. Descriptive studies such as ours are a prerequisite for research to determine causal pathways or develop predictive models. Measurement error is probable as some data was self-reported and collected retrospectively. Specifically, though self-reported prepregnancy weight may be biased due to underestimation,[40] self-report reflects typical clinical practice. Only total GWG, not longitudinal GWG, was collected, reducing precision[41] 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 was 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 SES, we may have underestimated the association between these characteristics and GWG.

The percentages of women within IOM GWG adequacy categories in our population (26.8% insufficient, 36.1% excessive) were relatively similar to those found in recent meta-analyses (LifeCycle: 21.5% insufficient, 42.0% excessive;[42] Goldstein et al.: 23% insufficient, 47% excessive[6]). Nonetheless, the majority of women in our study gained either insufficiently or excessively and the average GWG of women with normal weight BMI (13.8kg, SD 4.8) exceeded the current French guidelines, suggesting additional research within nationally-

representative samples of the French population is necessary to define adequate GWG and clarify national guidelines.

Compared to a recent systematic review of North American and European pregnant women,[42] our population had a similar prepregnancy BMI profile. However, compared to a separate systematic review which was not limited to North American and European women,[6] our French population had a lower percentage entering pregnancy with overweight or obese prepregnancy BMI (29% versus 38%). Though some previous studies also reported increased GWG in primiparous compared to multiparous,[25,32,42-44] a recent systematic review concluded that the evidence is inconsistent and that the role of parity on GWG is likely indirect and complex.[45]

Within our population, prepregnancy BMI was one of the most important maternal characteristics associated with GWG. The noted trends of an inverse relationship between prepregnancy BMI and GWG,[1,42-44,46-48] higher likelihood of insufficient GWG among women with underweight or obese BMI and of excessive GWG among women with overweight or obese BMI[13-15,19,32,49] compared to women with normal weight prepregnancy BMI, and generally lower percentages of women achieving adequate GWG with increasing BMI category[47,50] were also consistent with previous studies, including studies within French populations.[11,29,30] Though some differences were noted related to average GWG (with lower,[29] higher[11], and similar estimates[30]) and GWG adequacy (varying results depending on BMI category)[11,29,31] compared to the other French studies, differences may be attributed to differences in study design (retrospective versus prospective; nationally-representative versus limited/local hospital-based), location, GWG classification method (accounting for GA at delivery), and inclusion/exclusion criteria (women with pre-existing conditions excluded or not), with our study being the first in France to provide

nationally-representative estimates. Regardless, special attention should be paid to the specific needs of women entering pregnancy with overweight or obese prepregnancy BMI, including information related to GWG recommendations and the importance of physical activity and nutritional support to optimize GWG and neonatal outcomes.[1,51] Lastly, future research should address uncertainties regarding GWG guidelines in this population.[48,52,53] Additionally, smoking reduction or cessation was associated with increased absolute GWG and excessive GWG. Prior studies also found increased absolute GWG[21,22,54] and increased excessive GWG[14,19,21,54] among women who quit smoking in pregnancy due to physiologic changes to the metabolism and central nervous system resulting in increased appetite and the behavioral substitution of cigarettes with consumption of sugary foods.[55] Given the obvious benefits of quitting smoking during pregnancy, smokers intending to reduce/stop smoking during pregnancy should be provided additional nutritional and psychological support to avoid adverse effects of excessive GWG and educated on the use of nicotine replacement therapies (e.g., nicotine patches).

We identified several social factors associated with GWG in France. In line with previous studies, we found that insufficient prenatal care was associated with insufficient GWG.[15,20,23] Though some previous studies also found lower education was associated with insufficient[16,50,56]/low[7] or excessive weight gain,[13,16,56] others found that the associations between education and GWG differed by maternal BMI[19,24] or no differences.[17] In line with previous studies which found increased excessive GWG with younger maternal age,[13,14,18,50] we note a small decrease in excessive GWG among mothers over 35 years of age. Conflicting results have been found related to immigration: some previous research has reported higher GWG and increased excessive GWG in foreign nationals[26] or recent immigrants.[14] Similar to our findings, previous studies found insufficient GWG increased among foreign-born

women[15] or excessive GWG decreased among women of non-European ancestry living in The Netherlands.[17] In addition to social factors, a deeper understanding of the underlying cultural context and social conditions, both in the origin and arrival country, is important to develop specific strategies to improve care for vulnerable populations and ensure low-income women can achieve a nutritionally adequate diet. As midwives and obstetricians have limited knowledge of GWG recommendations,[57] informing clinicians on guidelines is also vital.

Conclusions

In France, a minority of women achieves adequate GWG. Maternal prepregnancy BMI and quitting smoking in pregnancy were associated with not achieving GWG recommendations, with additional associations found for maternal social factors. To promote adequate GWG and optimize pregnancy outcomes, support tailored to the specific needs of these at-risk groups is needed, including education related to appropriate GWG, physical activity, and nutrition in pregnancy and social support for disadvantaged/vulnerable populations. Given the uncertainties regarding the current IOM recommendations and their applicability in the non-United States populations of pregnant women, additional research within nationally-representative samples is needed to evaluate the associations between GWG and pregnancy outcomes and to ensure recommendations are appropriate for use outside the United States.

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Supplementary materials

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)

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)

Footnotes

Patient consent for publication: Not required

Ethics approval: Each survey cycle was approved by the National Council on Statistical Information (Comité du Label; 2016 approval number 2016X703SA), the French Commission on Information Technology and Liberties ([CNIL]; 2016 registration number 915197), and the Inserm ethics committee (2016 approval IRB00003888 no. 14-191).

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

	n (%)	**GWG (kg)** mean (SD)	**Insufficient GWG** n (%)	**Adequate GWG** n (%)	**Excessive GWG** n (%)
Overall	24850	13.0 (5.6)	6606 (26.8)	9106 (37.0)	8892 (36.1)
BMI[b]					
Underweight	1960 (8.0)	13.9 (4.8)	762 (38.9)	785 (40.1)	411 (21.0)
Normal weight	15506 (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 (0.95)	3.6 (8.3)	128 (54.7)	50 (21.4)	56 (23.9)
Parity					
Multiparous	14061 (56.7)	12.4 (5.6)	3972 (28.6)	5180 (37.2)	4755 (34.2)
Primiparous	10722 (43.3)	13.7 (5.6)	2617 (24.6)	3897 (36.6)	4123 (38.8)

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 delivery;[33,34] 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 [≥40])[35]

Table 2. Maternal characteristics and association with GWG (French National Perinatal Survey 2010 and 2016; N=24026 in adjusted model)

	N	**% of the sample**	**GWG (kg)** mean (SD)	**Adjusted[a] difference in GWG (kg)** diff (95% CI)
Parity				
Multiparous	14061	56.7	12.4 (5.6)	0.00 (Reference)
Primiparous	10722	43.3	13.7 (5.6)	0.69 (0.54, 0.83)
BMI[b]				
Underweight	1960	8.0	13.9 (4.8)	0.00 (-0.30, 0.31)
Normal weight	15506	62.9	13.8 (4.8)	0.00 (Reference)
Overweight	4545	18.4	12.2 (6.0)	-1.6 (-1.8, -1.4)
All obese	2625	10.7	8.6 (7.4)	-5.1 (-5.4, -4.8)
Obese class I	1802	7.3	9.8 (6.7)	-3.9 (-4.3, -3.6)
Obese class II	589	2.4	7.0 (7.7)	-6.7 (-7.3, -6.2)
Obese class III	234	0.9	3.6 (8.3)	-10.2 (-11.1, -9.3)
Age				
<25 years	3716	15.0	13.4 (6.3)	-0.04 (-0.30, 0.23)
25-29 years	8126	32.7	13.2 (5.7)	0.00 (Reference)
30-34 years	8079	32.5	12.9 (5.4)	0.05 (-0.15, 0.26)
>35 years	4918	19.8	12.5 (5.5)	-0.02 (-0.25, 0.22)
Country or region of birth				
France	20398	82.2	13.2 (5.5)	0.00 (Reference)
Europe	957	3.9	13.0 (5.7)	0.32 (-0.13, 0.76)
Northern Africa	1720	6.9	12.1 (6.1)	-0.20 (-0.55, 0.16)
Sub-Saharan Africa	1024	4.1	11.2 (6.8)	-0.58 (-1.0, -0.14)
Other	719	2.9	12.5 (5.2)	0.05 (-0.47, 0.56)
Employment during pregnancy				
None	7089	28.7	12.3 (6.4)	0.06 (-0.23, 0.35)
Stopped working before 14+0 wks gestation	1595	6.5	13.8 (6.3)	1.2 (0.76, 1.5)
Stopped working 14+0 to 27+6 wks gestation	6701	27.1	13.5 (5.5)	0.62 (0.36, 0.88)
Stopped working 28+0 to 31+6 wks gestation	4243	17.2	13.2 (4.9)	0.26 (-0.02, 0.54)
Work working at or after 32+0 wks gestation	4743	19.2	13.0 (4.9)	0.00 (Reference)
Work with unknown stop point	317	1.3	12.8 (5.6)	0.13 (-0.68, 0.93)
Education				
Less than high school	2158	8.7	11.9 (6.8)	0.58 (0.18, 0.98)
High school	9157	37.1	13.1 (6.3)	0.85 (0.57, 1.1)
1-2 years post graduation	5086	20.6	13.2 (5.3)	0.65 (0.36, 0.93)
3-4 years post graduation	4466	18.1	13.0 (4.9)	0.18 (-0.10, 0.46)
≥5 years post graduation	3798	15.4	12.9 (4.5)	0.00 (Reference)
Social deprivation[c]				
No	20424	82.2	13.1 (5.4)	0.00 (Reference)
Yes	4414	17.8	12.5 (6.6)	-0.06 (-0.26, 0.14)
Smoking habits before, during pregnancy				
Non smoker	17216	69.9	12.4 (5.3)	0.00 (Reference)
<10 cig/d, stopped	1855	7.5	14.4 (5.3)	1.5 (1.1, 1.8)
≥10 cig/d, stopped	1402	5.7	16.2 (5.9)	3.3 (2.9, 3.7)

≥10 cig/d, <10 cig/d	2185	8.9	14.0 (6.2)	1.3 (0.93, 1.6)
<10 cig/d, <10 cig/d	845	3.4	13.4 (6.4)	0.87 (0.38, 1.4)
≥10 cig/d, ≥10 cig/d	1081	4.4	12.4 (6.5)	0.10 (-0.36, 0.55)
Increased smoking[d]	47	0.2	13.6 (5.4)	1.1 (-0.87, 3.2)
Insufficient care[e]				
No	23515	94.7	13.1 (5.6)	0.00 (Reference)
Yes	1328	5.3	11.5 (6.4)	-0.91 (-1.2, -0.60)
Diabetes[f]				
No	22414	91.5	13.2 (5.5)	
Yes, diet controlled	633	2.6	10.2 (7.0)	
Yes, insulin controlled	1458	5.9	11.1 (6.5)	
Preexisting hypertension[f]				
No	24229	98.0	13.0 (5.6)	
Yes	504	2.0	11.7 (7.3)	

Abbreviations: GWG=Gestational Weight Gain; BMI= Body mass index; SD= standard deviation; CI= confidence interval; IOM= Institute of Medicine

[a]Adjusted on all covariates (except diabetes and pre-existing hypertension), survey year, gestational age at delivery, and mother's height; BMI included in models for other covariates as 4-level variable (underweight, normal weight, overweight, obese)

[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 [≥40])[35]

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

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

[e]Late declaration of pregnancy or insufficient sonograms or prenatal visits based on gestational age at delivery

[f]Not included in adjusted models because medical conditions are mediators of the relationship between maternal characteristics/social factor, the focus of this study.

Table 3. Associations between maternal characteristics and insufficient or excessive GWG[a] in multivariable logistic regression models (French National Perinatal Survey 2010 and 2016; N=23931)

	Insufficient GWG aOR[b] (95% CI)	**Excessive GWG** aOR[b] (95% CI)
Parity		
Multiparous	1.00 (Reference)	1.00 (Reference)
Primiparous	0.92 (0.86, 0.99)	1.2 (1.2, 1.3)
BMI[c]		
Underweight	1.4 (1.2, 1.5)	0.67 (0.59, 0.76)
Normal weight	1.00 (Reference)	1.00 (Reference)
Overweight	0.69 (0.62, 0.77)	2.8 (2.6, 3.1)
All obese	1.5 (1.4, 1.7)	3.3 (2.9, 3.6)
Obese class I	1.2 (1.0, 1.4)	3.8 (3.4, 4.3)
Obese class II	1.9 (1.5, 2.4)	2.4 (2.0, 3.0)
Obese class III	3.4 (2.4, 4.7)	1.3 (0.90, 2.0)
Age (years)		
<25 years	1.1 (0.96, 1.2)	1.0 (0.94, 1.1)
25-29 years	1.00 (Reference)	1.00 (Reference)
30-34 years	0.98 (0.90, 1.1)	0.98 (0.91, 1.1)
>35 years	0.99 (0.90, 1.1)	0.94 (0.85, 1.0)
Country or region of birth		
France	1.00 (Reference)	1.00 (Reference)
Europe	0.90 (0.75, 1.1)	1.1 (0.93, 1.3)
Northern Africa	1.1 (1.0, 1.3)	1.1 (0.98, 1.3)
Sub-Saharan Africa	1.2 (1.0, 1.5)	1.1 (0.93, 1.3)
Other	1.0 (0.83, 1.2)	1.1 (0.87, 1.3)
Employment during pregnancy		
None	1.2 (1.0, 1.3)	1.2 (1.1, 1.3)
Stopped working before 14+0 weeks gestation	0.98 (0.83, 1.1)	1.6 (1.4, 1.8)
Stopped working 14+0 to 27+6 weeks gestation	0.91 (0.82, 1.0)	1.2 (1.1, 1.4)
Stopped working 28+0 to 31+6 weeks gestation	0.93 (0.84, 1.0)	1.1 (0.96, 1.2)
Work working at or after 32+0 weeks gestation	1.00 (Reference)	1.00 (Reference)
Work with unknown stop point	1.1 (0.78, 1.4)	1.0 (0.76, 1.4)
Education		
Less than high school	1.2 (1.0, 1.4)	1.5 (1.3, 1.7)
High school	1.0 (0.90, 1.1)	1.5 (1.3, 1.6)
1-2 years post-graduation	0.93 (0.83, 1.0)	1.3 (1.2, 1.5)
3-4 years post-graduation	1.0 (0.90, 1.1)	1.1 (1.0, 1.2)
≥5 years post-graduation	1.00 (Reference)	1.00 (Reference)
Social deprivation[d]		
No	1.00 (Reference)	1.00 (Reference)
Yes	1.1 (0.97, 1.2)	1.0 (0.92, 1.1)
Smoking habits before, during pregnancy		
Non smoker	1.00 (Reference)	1.00 (Reference)
<10 cig/d, stopped	0.66 (0.57, 0.75)	1.4 (1.3, 1.6)
≥10 cig/d, stopped	0.60 (0.49, 0.72)	2.6 (2.3, 2.9)

≥10 cig/d, <10 cig/d	0.90 (0.79, 1.0)	1.5 (1.4, 1.7)
<10 cig/d, <10 cig/d	1.1 (0.90, 1.3)	1.5 (1.3, 1.8)
≥10 cig/d, ≥10 cig/d	1.2 (0.99, 1.4)	1.2 (1.0, 1.4)
Increased smoking[e]	0.67 (0.30, 1.5)	1.4 (0.72, 2.7)
Insufficient care[f]		
Yes	1.2 (1.1, 1.4)	0.86 (0.74, 1.0)
No	1.00 (Reference)	1.00 (Reference)

Abbreviations: GWG=Gestational Weight Gain; BMI= Body mass index; SD= standard deviation; CI= confidence interval; IOM= Institute of Medicine; aOR= adjusted odds ratio

[a]Based on 2009 IOM thresholds,[1] accounting for gestational age at delivery;[33,34] considered insufficient GWG if below recommendation, adequate if within recommendation, or excessive if above recommendation

[b]Adjusted on all covariates, survey year, and mother's height; BMI included in models for other covariates as 4-level variable (underweight, normal weight, overweight, obese)

[c]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])[35]

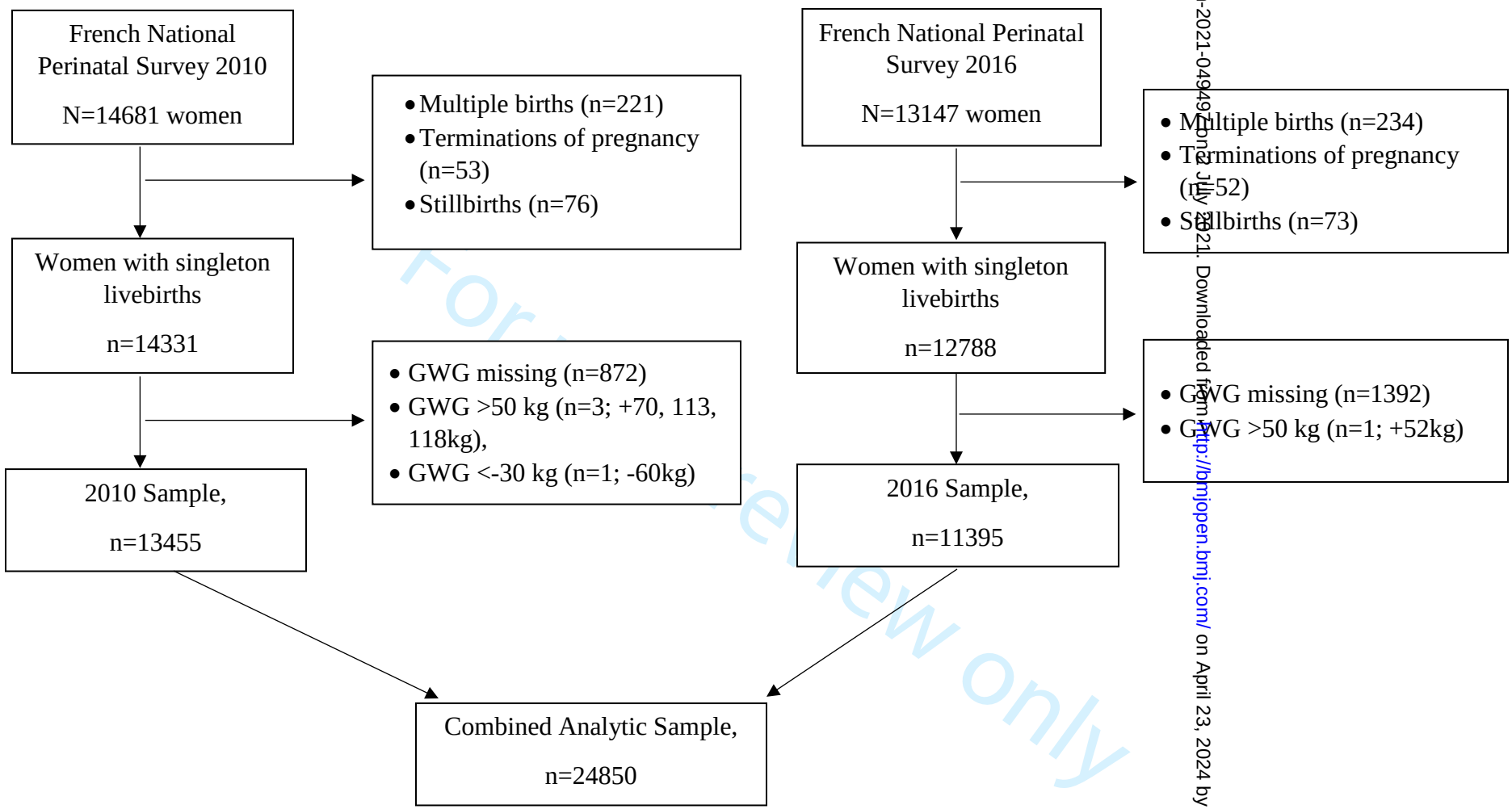
[d]No stable home (homeless or living in a hotel or caravan) and/or no salary nor unemployment allowance

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

[f]Late declaration of pregnancy or insufficient sonograms or prenatal visits based on gestational age at delivery

Figure legends

Figure 1: Participant flow chart



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 (0.98)	4.2 (8.1)	70 (53.8)	22 (16.9)	38 (29.2)	104 (0.92)	2.8 (8.6)	58 (55.8)	28 (26.9)	18 (17.3)
Parity										
Multiparous	7510 (56.1)	12.6 (5.5)	2055 (27.7)	2821 (38.1)	2530 (34.2)	6551 (57.5)	12.2 (5.8)	1917 (29.5)	2359 (36.3)	2225 (34.2)
Primiparous	5881 (43.9)	13.9 (5.5)	1371 (23.5)	2156 (37.0)	2295 (39.4)	4841 (42.5)	13.4 (5.7)	1246 (25.9)	1741 (36.2)	1828 (38.0)

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 delivery;[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 [≥40])[4]

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 (%)
Parity		
Multiparous	14061 (56.7)	1100 (63.5)
Primiparous	10722 (43.3)	632 (36.5)
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 (0.95)	3 (1.8)
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 before 14+0 wks gestation	1595 (6.5)	20 (3.0)
Stopped working 14+0 to 27+6 wks gestation	6701 (27.1)	58 (8.7)
Stopped working 28+0 to 31+6 wks gestation	4243 (17.2)	24 (3.6)
Work working at or after 32+0 wks gestation	4743 (19.2)	40 (6.0)
Work with unknown stop point	317 (1.3)	124 (18.5)
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)
<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)
<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[c]	47 (0.19)	1 (0.24)
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: BMI= Body mass index

[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 declaration of pregnancy or insufficient sonograms or prenatal visits based on gestational age at delivery

References

1. Institute of Medicine. Weight gain during pregnancy: Reexamining the guidelines. 2009:1-13.
2. Bodnar LM, Siega-Riz AM, Simhan HN, Himes KP, Abrams B. Severe obesity, gestational weight gain, and adverse birth outcomes. *American Journal of Clinical Nutrition*. 2010;91(6):1642-1648.
3. Liu J, Gallagher AE, Carta CM, Torres ME, Moran R, Wilcox S. Racial differences in gestational weight gain and pregnancy-related hypertension. *Annals of Epidemiology*. 2014;24(6):441-447.
4. World Health Organization. Global database on body mass index: BMI classification. 2006. https://www.who.int/nutrition/databases/bmi/en/. Updated 2017.

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-8
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-8
Bias	9	Describe any efforts to address potential sources of bias	6-7; 8-9
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-9
		(*b*) Describe any methods used to examine subgroups and interactions	n/a
		(*c*) Explain how missing data were addressed	9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	n/a

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		€ Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	n/a
		© Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10; Table 1-2; eTable 1
		(b) Indicate number of participants with missing data for each variable of interest	9
		© *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	n/a
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	n/a
		Cross-sectional study—Report numbers of outcome events or summary measures	10; Table 1-2; eTable 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10-12; Tables 2-3
		(*b*) Report category boundaries when continuous variables were categorized	Tables 2-3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	n/a
Discussion			
Key results	18	Summarise key results with reference to study objectives	12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-16
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	24

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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

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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: French National Perinatal Survey 2010 and 2016, a population-based, nationally representative study

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 prepregnancy weight (kg) and categorized as "insufficient", "adequate", or "excessive" using 2009 Institute of Medicine thresholds. Classification accounted for prepregnancy body mass index (kg/m^2; underweight [<18.5], normal weight [18.5-24.9], overweight [25-29.9], obese [≥30]) and gestational age at delivery. 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 13.0kg (standard deviation 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 (versus normal weight; adjusted OR [aOR] 1.4, 95%CI 1.2, 1.5) and obese (aOR 1.5, 95%CI 1.4, 1.7) BMI. Excessive GWG was associated with overweight (aOR 2.8, 95%CI 2.6, 3.1) and obese BMI (aOR 3.3, 95%CI 2.9, 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, 1.0; excessive: aOR 1.2, 95% CI 1.2, 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, support is needed for women with characteristics associated with insufficient and excessive GWG, including nutritional advice for women smoking during pregnancy or with high or low BMI.

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 (NPS) 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 prepregnancy BMI and GWG) was self-reported and collected retrospectively, which could result in measurement error

Introduction

Due to demographic and lifestyle changes, women are entering pregnancy with higher body mass index (BMI) and gaining excessive pregnancy weight,[1-4] concerning trends as both 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 cesarean 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 United States' Institute of Medicine (IOM; now National Academy of Medicine), provided updated GWG guidelines, stratified by maternal prepregnancy 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 prepregnancy BMI, whether separate guidelines are needed by obesity class is unclear due to a lack of evidence and subsequent studies suggest that women with severe obesity gaining below the recommendations should not 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 prepregnancy BMI, numerous maternal factors, including socio-demographic characteristics, are potentially associated with GWG.[8,15-27] However, evidence gaps exist, as these studies of GWG risk factors were largely conducted in the United States,[8,16,17,20,22,24,25] with further evidence needed in diverse populations,[1] and are not nationally-representative. Further, many had a relatively small sample size (N<1,000),[19,22,23,26,27] used GWG guidelines[8,16,17,19,22] or data collected prior to the 2009 IOM guidelines,[15,18,25] or focused narrowly on specific risk factors.[22-26]

In France, BMI and inadequate GWG prevalence 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 to the United States (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 (e.g., 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 upon 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 organizational 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 delivery) using a standardized 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 >50kg or loss >30kg[9,36] (n=4 in 2010; n=1 in 2016). Based on missing/implausible GWG, <10% of women with singleton livebirths 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 prepregnancy weight. Then, *GWG adequacy* (insufficient, adequate, excessive) was determined by maternal prepregnancy BMI (kg/m^2; using self-reported height and prepregnancy weight; underweight [<18.5], normal weight [18.5-24.9], overweight [25-29.9], obese [≥30])[37] and was standardized across gestational ages using a previously described method[38,39] based on the assumptions underlying the 2009 GWG IOM guidelines (Panel 1).

Panel 1: GWG adequacy determination using a previously described method[38,39]

	IOM recommendations/assumptions for GWG at 40 weeks gestation			Conversion to proportions of GWG achieved	
BMI (kg/m^2)	1st trimester GWG (kg)	Rate of GWG (kg/week)	Recommended range (kg)	Expected GWG at 40 weeks	Recommended *range of proportion* of GWG[39]
Underweight (<18.5)	2	0.51	12.5-18	15.77	0.79-1.14
Normal weight (18.5-24.9)	2	0.42	11.5-16	13.34	0.86-1.20
Overweight (25-29.9)	1	0.28	7.0-11.5	8.56	0.81-1.34
Obese (≥30)	0.5	0.22	5.0-9.0	6.44	0.78-1.41

1. *Expected GWG* at 40 weeks computed: Recommended first trimester gain + [(GA at delivery – 13)*Recommended rate of GWG]
   Example: Normal weight BMI: *Expected GWG*=13.34kg = (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 to *ranges of proportions* for her BMI group
   GWG adequacy classified as:
   - *Insufficient*: below lower bound
   - *Adequate:* within recommended range
   - *Excessive:* above upper bound

French guidelines for GWG (2007 French National Nutrition and Health Program [Programme National Nutrition et Santé])[40] differ from IOM guidelines, recommending GWG of 12kg for women with normal prepregnancy BMI, lower GWG (not under 7kg) for women with overweight or obese prepregnancy BMI, and higher GWG for women with underweight prepregnancy 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 utilized in clinical practice, we used the IOM guidelines in our analysis.

Covariates

Maternal characteristics collected by interview prior to hospital discharge utilized are: prepregnancy BMI (defined above; obesity further categorized 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; 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 post-graduation). Smoking was evaluated based on smoking prior to pregnancy versus in the 3rd trimester (for each time point: non-smoker/stopped smoking, <10 cigarettes per day [cig/d], ≥10cig/d), categorized as: non-smoker at both time points; <10cig/d, stopped; ≥10cig/d, stopped; ≥10cig/d, reduced to <10cig/d; <10cig/d, maintained at <10cig/d; ≥10cig/d, maintained at ≥10cig/d; increased smoking [combined groups of: non-smoker, increased to <10cig/d; non-smoker, increased to ≥10cig/d; <10cig/d, increased to ≥10cig/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 three completed months and no nuchal translucency measurement in first trimester) or insufficient sonograms (<2 if GA at delivery 24-33 weeks; <3 if GA at delivery 34 weeks or later) or prenatal visits (<3 if GA at delivery 24-27 weeks; <4 if GA at delivery 28-31 weeks; <5 if GA at delivery 32-35 weeks; <6 if GA at delivery 36 weeks or later), consistent with French guidelines for low risk women.[42] Prepregnancy

conditions/pregnancy complications, obtained from chart abstraction and used for descriptive purposes, included diabetes in pregnancy (no; diet controlled; insulin controlled) and preexisting hypertension.

Statistical analysis

To describe the GWG profile of our cohort, for both survey years combined and individually, mean GWG (with standard deviations [SD]) 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% confidence intervals [CIs]) between categories of maternal characteristics, with a mean GWG difference of >1kg considered clinically significant. Similarly, adjusted polytomous logistic regression models were used to examine the association between maternal characteristics and GWG adequacy (adjusted odds ratio [aOR], 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 (meters), GA at delivery (days; linear models only, as GA at delivery accounted for in definition of GWG adequacy), and survey year. Prepregnancy conditions/pregnancy complications were not included in adjusted models as our primary interest was identifying social factors and because diabetes and hypertension may be mediators of the association between maternal characteristics and GWG. 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 6-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 analytic 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 prepregnancy BMI (1%), employment during pregnancy (1%), education (1%), smoking status (1%), and diabetes (1%; not included in multivariable models).

We used SAS software version 9.4 for Windows (SAS Institute Inc., Cary, NC) for statistical analyses.

Patient and public involvement

A network representing French user associations on questions related to pregnancy, childbirth and infancy were 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 13.0kg (SD 5.6; Table 1), decreasing from 13.2kg (SD 5.6) in 2010 to 12.7kg (SD 5.7) in 2016

(eTable 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 2), almost 20% of women were born outside of France, a majority were normal weight BMI entering pregnancy, 30% smoked either before or during pregnancy, 2.0% had preexisting hypertension, and 8.5% had diabetes in pregnancy. Compared to women excluded due to missing or implausible GWG, women included in our analytic sample were more likely to be primiparous, have a lower prepregnancy BMI, have modified their smoking habits during pregnancy, and have characteristics indicative of higher socio-economic status (eTable 2).

In unadjusted analysis, clinically significant differences (>1kg) in mean GWG were found for all maternal characteristics except maternal age and social deprivation (Table 2), 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 (11.1kg, SD 6.5 among women with insulin controlled and 10.2kg, SD 7.0 among women with diet controlled diabetes versus 13.2kg, SD 5.5 among women without diabetes during pregnancy) or preexisting hypertension (11.7kg, SD 7.3 versus 13.0kg, SD 5.6 among women without preexisting hypertension). In adjusted models, clinically significant differences in mean GWG persisted for maternal prepregnancy BMI, employment in pregnancy, and smoking habits only.

In polytomous logistic regression models (Table 3), 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 prepregnancy 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 prepregnancy BMI was inversely associated with excessive GWG.

When adjusted analyses were repeated to evaluate obesity classes I-III separately (Table 4), the trend of greater decreases in GWG compared to 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 adequate GWG based on the 2009 IOM guidelines. Insufficient GWG was increased among women with underweight or obese prepregnancy BMI, while excessive GWG was increased among women with overweight or obese prepregnancy BMI. When examining obesity classes separately, insufficient GWG increased from obesity class I to III, while excessive GWG decreased from obesity class I to III. Excessive GWG was also increased among women who maintained or reduced their smoking levels in pregnancy. Primiparity and maternal characteristics

indicative of lower socioeconomic status (low education level, insufficient prenatal care, maternal birth in sub-Saharan Africa) were also associated with inadequate GWG.

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 meta-analyses (LifeCycle: 21.5% insufficient, 42.0% excessive;[43] Goldstein et al.: 23% insufficient, 47% excessive[7]). Examining GWG by BMI class, our findings (inverse relationship between prepregnancy 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. Clinicians providing prenatal care should counsel women regarding appropriate GWG for their prepregnancy BMI and provide information related to and nutritional and physical activity support to meet recommendations,[1] in particular for women with underweight, overweight, or obese BMI as these groups are more likely to have inadequate GWG and are therefore at higher risk of related adverse outcomes. As midwives and obstetricians have limited knowledge of GWG recommendations,[51] informing clinicians on guidelines is also vital.

The average GWG (13.8kg, 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 (varying results depending on BMI category)[12,30,32] in the French population differed between studies. The differences between the French study results may be attributed to differences in study design (retrospective versus prospective; nationally-representative versus limited/local hospital-based), location, GWG classification method (accounting for GA at delivery 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 this population,[14] we extended our analyses to compare mean GWG and GWG adequacy between obesity classes. Our results are consistent with previous studies, 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, 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 physiologic changes to the metabolism and central nervous system resulting in increased appetite and the behavioral 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 (e.g., 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 (e.g., nicotine patches).

Finally, we found that a number of maternal and social characteristics were associated with GWG adequacy, though consistency with prior literature was mixed. While we found increased GWG in primiparas compared to multiparas, a recent 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, some studies have found increased excessive GWG with younger maternal age.[15,19,49,50] Results for education have been mixed, with some previous studies also finding lower education was associated with insufficient[5,17,50]/low[8] or excessive weight gain[5,17,49] but others 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[27] or recent immigrants[15] but others finding insufficient GWG increased among foreign-born women[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,[16,21,24] in line with our results. Given the 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 upon 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 (e.g., maternal age, GA) available from birth certificate and hospital discharge statistics in the corresponding years.[28,29] By accounting for GA at delivery in our definition of GWG adequacy and controlling for GA at delivery 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 deliveries (5.3%) and preliminary sensitivity analyses of term pregnancies within our cohort were consistent with our main analyses (data not reported), providing further evidence that biases due to GA at delivery were minimized. 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 was self-reported and collected retrospectively. Specifically, self-reported prepregnancy weight and maternal weight at delivery may be biased due to underestimation.[63] However, because reporting of weight gain during pregnancy in medical records is not standardized 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 was 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 adequate GWG. Maternal prepregnancy BMI, continuing or quitting smoking in pregnancy, and lower socioeconomic status were associated with not achieving GWG recommendations. To promote adequate GWG and optimize pregnancy outcomes, support tailored to the specific needs of these at-risk groups is needed, including education related to appropriate GWG, physical activity, and nutrition in pregnancy and social support for disadvantaged/vulnerable populations. Given the uncertainties regarding the current IOM GWG recommendations, additional research within nationally-representative samples outside the United States and within BMI obesity classes is needed.

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Supplementary materials

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)

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)

Footnotes

Patient consent for publication: Not required

Ethics approval: Each survey cycle was approved by the National Council on Statistical Information (Comité du Label; 2016 approval number 2016X703SA), the French Commission on Information Technology and Liberties ([CNIL]; 2016 registration number 915197), and the Inserm ethics committee (2016 approval IRB00003888 no. 14-191).

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

	n (%)	**GWG (kg)** mean (SD)	**Insufficient GWG** n (%)	**Adequate GWG** n (%)	**Excessive GWG** n (%)
Overall	24850	13.0 (5.6)	6606 (26.8)	9106 (37.0)	8892 (36.1)
BMI[b]					
Underweight	1960 (8.0)	13.9 (4.8)	762 (38.9)	785 (40.1)	411 (21.0)
Normal weight	15506 (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)

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 delivery;[38,39] 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 [≥40])[37]

Table 2. Distribution of maternal characteristics in the sample and GWG associated with these characteristics (French National Perinatal Survey 2010 and 2016)

	n (%)	GWG (kg) mean (SD)	Adjusted[a] difference in GWG (kg) diff (95% CI)
BMI[b]			
Underweight	1960 (8.0)	13.9 (4.8)	0.0 (-0.3, 0.3)
Normal weight	15506 (62.9)	13.8 (4.8)	reference
Overweight	4545 (18.4)	12.2 (6.0)	**-1.6 (-1.8, -1.4)**
Obese	2625 (10.7)	8.6 (7.4)	**-5.1 (-5.4, -4.8)**
Parity			
Multiparous	14061 (56.7)	12.4 (5.6)	reference
Primiparous	10722 (43.3)	13.7 (5.6)	0.7 (0.5, 0.8)
Age			
<25 years	3716 (15.0)	13.4 (6.3)	-0.0 (-0.3, 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, 0.3)
≥35 years	4918 (19.8)	12.5 (5.5)	-0.0 (-0.3, 0.2)
Country or region of birth			
France	20398 (82.2)	13.2 (5.5)	reference
Europe	957 (3.9)	13.0 (5.7)	0.3 (-0.1, 0.8)
Northern Africa	1720 (6.9)	12.1 (6.1)	-0.2 (-0.6, 0.2)
Sub-Saharan Africa	1024 (4.1)	11.2 (6.8)	-0.6 (-1.0, -0.1)
Other	719 (2.9)	12.5 (5.2)	0.0 (-0.5, 0.6)
Employment during pregnancy			
None	7089 (28.7)	12.3 (6.4)	0.1 (-0.2, 0.3)
Stopped working during pregnancy			
Before 14+0 wks gestation	1595 (6.5)	13.8 (6.3)	**1.2 (0.8, 1.5)**
14+0 to 27+6 wks gestation	6701 (27.1)	13.5 (5.5)	0.6 (0.4, 0.9)
28+0 to 31+6 wks gestation	4243 (17.2)	13.2 (4.9)	0.3 (-0.0, 0.5)
Unknown stop point	4743 (19.2)	12.8 (5.6)	0.1 (-0.7, 0.9)
Continued working to ≥32 wks 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, 1.0)
High school	9157 (37.1)	13.1 (6.3)	0.8 (0.6, 1.1)
1-2 years post-graduation	5086 (20.6)	13.2 (5.3)	0.6 (0.4, 0.9)
3-4 years post-graduation	4466 (18.1)	13.0 (4.9)	0.2 (-0.1, 0.5)
≥5 years post-graduation	3798 (15.4)	12.9 (4.5)	reference
Social deprivation[c]			
No	20424 (82.2)	13.1 (5.4)	reference
Yes	4414 (17.8)	12.5 (6.6)	-0.1 (-0.3, 0.1)
Smoking habits before, during pregnancy			
Non smoker	17216 (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, 1.8)**
≥10 cig/d, stopped	1402 (5.7)	16.2 (5.9)	**3.3 (2.9, 3.7)**
≥10 cig/d, <10 cig/d	2185 (8.9)	14.0 (6.2)	**1.3 (0.9, 1.6)**

Maintained smoking level in pregnancy			
<10 cig/d, <10 cig/d	845 (3.4)	13.4 (6.4)	0.9 (0.4, 1.4)
≥10 cig/d, ≥10 cig/d	1081 (4.4)	12.4 (6.5)	0.1 (-0.4, 0.5)
Increased smoking in pregnancy[d]	47 (0.2)	13.6 (5.4)	1.1 (-0.9, 3.2)
Insufficient care[e]			
No	23515 (94.7)	13.1 (5.6)	reference
Yes	1328 (5.3)	11.5 (6.4)	-0.9 (-1.2, -0.6)

Abbreviations: GWG= gestational weight gain; SD= standard deviation; CI= confidence interval; BMI= body mass index; cig/d= cigarettes per day; GA= gestational age

[a]Estimated using adjusted linear regression models; adjusted on all covariates in table, survey year, GA at delivery, and mother's height

[b]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30[37]

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

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

[e]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 delivery 24-33 weeks; <3 if GA at delivery 34 weeks or later) or prenatal visits (<3 if GA at delivery 24-27 weeks; <4 if GA at delivery 28-31 weeks; <5 if GA at delivery 32-35 weeks; <6 if GA at delivery 36 weeks or later), consistent with French guidelines for low risk women

BOLD: clinically (>1kg) and statistically significant mean difference

Table 3. Associations between maternal characteristics and insufficient or excessive GWG[a] in multivariable logistic regression models (French National Perinatal Survey 2010 and 2016; N=23931)

	Insufficient GWG aOR[b] (95% CI)	**Excessive GWG** aOR[b] (95% CI)
BMI[c]		
Underweight	**1.4 (1.2, 1.5)**	**0.7 (0.6, 0.8)**
Normal weight	reference	reference
Overweight	**0.7 (0.6, 0.8)**	**2.8 (2.6, 3.1)**
Obese	**1.5 (1.4, 1.7)**	**3.3 (2.9, 3.6)**
Primiparity (versus multiparous)	**0.9 (0.9, 1.0)**	**1.2 (1.2, 1.3)**
Age		
<25 years	1.1 (1.0, 1.2)	1.0 (0.9, 1.1)
25-29 years	reference	reference
30-34 years	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)
≥35 years	1.0 (0.9, 1.1)	0.9 (0.9, 1.0)
Country or region of birth (versus France)		
Europe	0.9 (0.8, 1.1)	1.1 (0.9, 1.3)
Northern Africa	1.1 (1.0, 1.3)	1.1 (1.0, 1.3)
Sub-Saharan Africa	**1.2 (1.0, 1.5)**	1.1 (0.9, 1.3)
Other	1.0 (0.8, 1.2)	1.1 (0.9, 1.3)
Employment during pregnancy		
None	**1.2 (1.0, 1.3)**	**1.2 (1.1, 1.3)**
Stopped working during pregnancy		
Before 14+0 wks gestation	1.0 (0.8, 1.1)	**1.6 (1.4, 1.8)**
14+0 to 27+6 wks gestation	0.9 (0.8, 1.0)	**1.2 (1.1, 1.4)**
28+0 to 31+6 wks gestation	0.9 (0.8, 1.0)	1.1 (1.0, 1.2)
Unknown stop point	1.1 (0.8, 1.4)	1.0 (0.8, 1.4)
Continued working to ≥32 wks gestation	reference	reference
Education (versus ≥5 years post-graduation)		
Less than high school	**1.2 (1.0, 1.4)**	**1.5 (1.3, 1.7)**
High school	1.0 (0.9, 1.1)	**1.5 (1.3, 1.6)**
1-2 years post-graduation	0.9 (0.8, 1.0)	**1.3 (1.2, 1.5)**
3-4 years post-graduation	1.0 (0.9, 1.1)	1.1 (1.0, 1.2)
Social deprivation[d]	1.1 (1.0, 1.2)	1.0 (0.9, 1.1)
Smoking habits before, during pregnancy (versus non-smokers)		
Decreased smoking in pregnancy		
<10 cig/d, stopped	**0.7 (0.6, 0.8)**	**1.4 (1.3, 1.6)**
≥10 cig/d, stopped	**0.6 (0.5, 0.7)**	**2.6 (2.3, 2.9)**
≥10 cig/d, <10 cig/d	0.9 (0.8, 1.0)	**1.5 (1.4, 1.7)**
Maintained smoking level in pregnancy		
<10 cig/d, <10 cig/d	1.1 (0.9, 1.3)	**1.5 (1.3, 1.8)**
≥10 cig/d, ≥10 cig/d	1.2 (1.0, 1.4)	**1.2 (1.0, 1.4)**
Increased smoking in pregnancy[e]	0.7 (0.3, 1.5)	1.4 (0.7, 2.7)
Insufficient care[f]	**1.2 (1.1, 1.4)**	0.9 (0.7, 1.0)

Abbreviations: GWG= gestational weight gain; aOR= adjusted odds ratio; CI= confidence interval; BMI= body mass index; cig/d= cigarettes per day; IOM= Institute of Medicine; GA= gestational age

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

[b]Estimated using polytomous logistic regression models; adjusted on all covariates in table, survey year, and mother's height

[c]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30[37]

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

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

[f]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 delivery 24-33 weeks; <3 if GA at delivery 34 weeks or later) or prenatal visits (<3 if GA at delivery 24-27 weeks; <4 if GA at delivery 28-31 weeks; <5 if GA at delivery 32-35 weeks; <6 if GA at delivery 36 weeks or later), consistent with French guidelines for low risk women

BOLD: statistically significant association (does not cross null)

Table 4. Association between maternal prepregnancy BMI[a] and GWG and GWG adequacy,[b] accounting for obesity classes I-III in adjusted regression models[c] (French National Perinatal Survey 2010 and 2016)

	N	GWG (kg) mean (SD)	Adjusted difference in GWG (kg) diff (95% CI)	Insufficient GWG aOR[b] (95% CI)	Excessive GWG aOR[b] (95% CI)
Underweight	1960	13.9 (4.8)	0.0 (-0.3, 0.3)	**1.4 (1.2, 1.5)**	**0.7 (0.6, 0.8)**
Normal weight	15506	13.8 (4.8)	reference	reference	reference
Overweight	4545	12.2 (6.0)	**-1.6 (-1.8, -1.4)**	**0.7 (0.6, 0.8)**	**2.8 (2.6, 3.1)**
Obese class I	1802	9.8 (6.7)	**-3.9 (-4.3, -3.6)**	**1.2 (1.0, 1.4)**	**3.8 (3.4, 4.3)**
Obese class II	589	7.0 (7.7)	**-6.7 (-7.3, -6.2)**	**1.9 (1.5, 2.4)**	**2.4 (2.0, 3.0)**
Obese class III	234	3.6 (8.3)	**-10.2 (-11.1, -9.3)**	**3.4 (2.4, 4.7)**	1.3 (0.9, 2.0)

Abbreviations: BMI= body mass index; GWG= gestational weight gain; SD= standard deviation; aOR= adjusted odds ratio; CI= confidence interval; IOM= Institute of Medicine; GA= gestational age at delivery

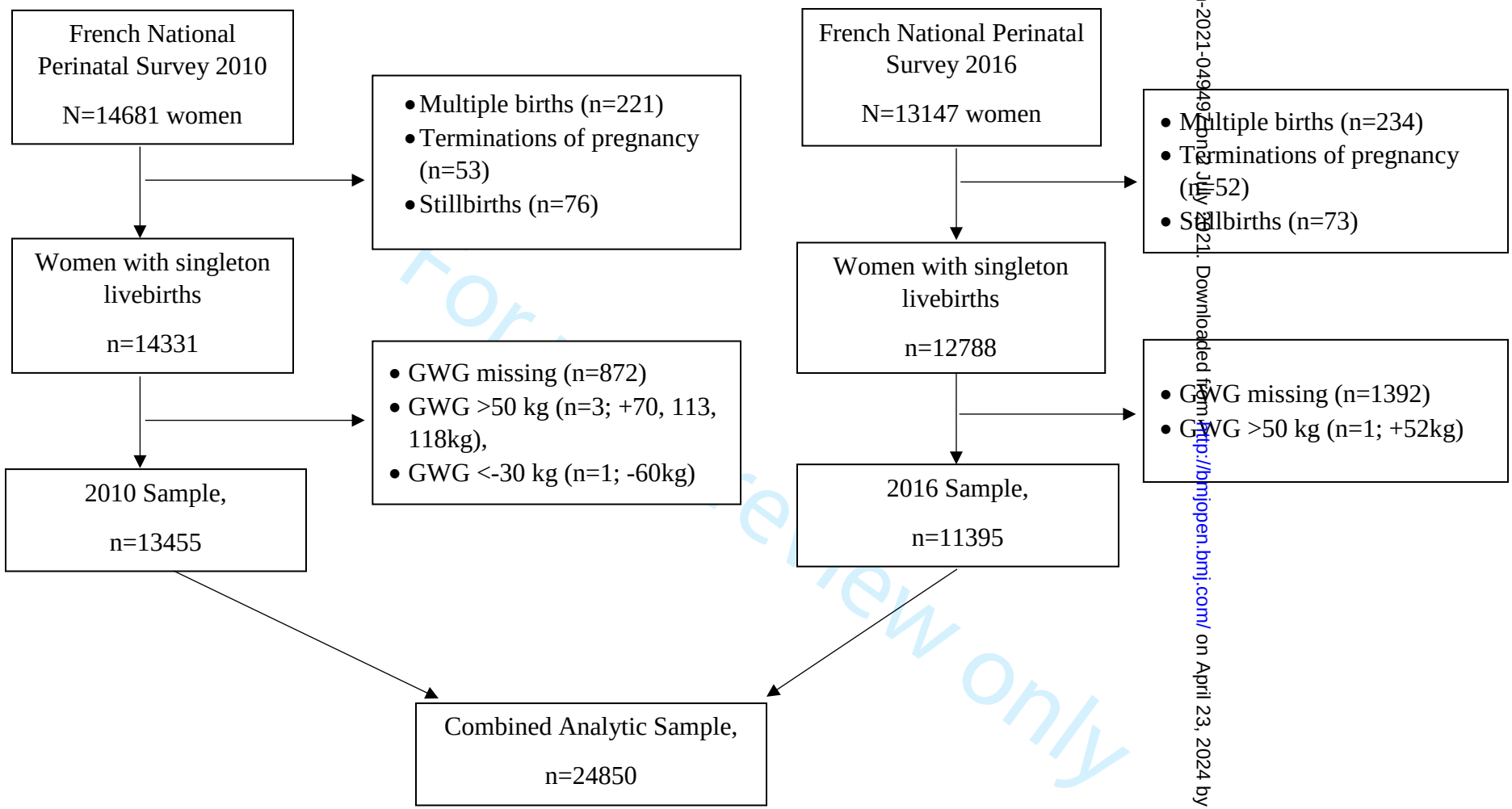
[a]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese class I: 30-34.9; obese class II: 35-39.9; obese class III: ≥40[37]

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

[c]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 delivery (linear models only)

Figure legends

Figure 1: Participant flow chart



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 delivery;[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 [≥40])[4]

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 delivery 24-33 weeks; <3 if GA at delivery 34 weeks or later) or prenatal visits (<3 if GA at delivery 24-27 weeks; <4 if GA at delivery 28-31 weeks; <5 if GA at delivery 32-35 weeks; <6 if GA at delivery 36 weeks or later), consistent with French guidelines for low risk women

References

1. Institute of Medicine. Weight gain during pregnancy: Reexamining the guidelines. 2009:1-13.
2. Bodnar LM, Siega-Riz AM, Simhan HN, Himes KP, Abrams B. Severe obesity, gestational weight gain, and adverse birth outcomes. *American Journal of Clinical Nutrition*. 2010;91(6):1642-1648.
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4. World Health Organization. Global database on body mass index: BMI classification. 2006. https://www.who.int/nutrition/databases/bmi/en/. Updated 2017.

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-9
Bias	9	Describe any efforts to address potential sources of bias	6-7; 9-10
Study size	10	Explain how the study size was arrived at	5-6; Fig 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	n/a
		(*c*) Explain how missing data were addressed	10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	n/a

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		€ Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6
		(b) Give reasons for non-participation at each stage	n/a
		© Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11; Table 1-2; eTable 1
		(b) Indicate number of participants with missing data for each variable of interest	10
		© *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	n/a
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	n/a
		Cross-sectional study—Report numbers of outcome events or summary measures	10-11; Table 1-2; eTable 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12; Tables 2-3
		(*b*) Report category boundaries when continuous variables were categorized	Tables 2-3
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12; Table 4
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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

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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 prepregnancy weight (kg) and categorized as "insufficient", "adequate", or "excessive" using 2009 Institute of Medicine thresholds. Classification accounted for prepregnancy body mass index (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 13.0kg (standard deviation 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 (versus normal weight; adjusted OR [aOR] 1.4, 95%CI 1.2, 1.5) and obese (aOR 1.5, 95%CI 1.4, 1.7) BMI. Excessive GWG was associated with overweight (aOR 2.8, 95%CI 2.6, 3.1) and obese BMI (aOR 3.3, 95%CI 2.9, 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, 1.0; excessive: aOR 1.2, 95% CI 1.2, 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 prepregnancy BMI and GWG) was 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 cesarean 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 United States' Institute of Medicine (IOM; now National Academy of Medicine), updated GWG guidelines, stratified by maternal prepregnancy 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 prepregnancy 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 prepregnancy BMI, numerous maternal factors, including socio-demographic characteristics, are potentially associated with GWG.[8,15-27] However, evidence gaps exist, as most studies of GWG risk factors were conducted in the United States[8,16,17,20,22,24,25] and many had a relatively small sample sizes (N<1,000),[19,22,23,26,27] used GWG guidelines[8,16,17,19,22] or data collected 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 United States.

In France, both maternal prepregnancy 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 to the United States (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 (e.g., 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 upon 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 organizational 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 standardized 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 >50kg or loss >30kg[9,36] (n=4 in 2010; n=1 in 2016). Based on missing/implausible GWG, <10% of women with singleton livebirths 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 prepregnancy weight. Then, *GWG adequacy* (insufficient, adequate, excessive) was determined by maternal prepregnancy BMI (kg/m^2; using self-reported height and prepregnancy weight; underweight [<18.5], normal weight [18.5-24.9], overweight [25-29.9], obese [≥30])[37] and was standardized 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 12kg for

women with normal prepregnancy BMI, lower GWG (not under 7kg) for women with overweight or obese prepregnancy BMI, and higher GWG for women with underweight prepregnancy 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 utilized in clinical practice, we used the IOM guidelines in our analysis.

Covariates

Maternal characteristics collected by interview prior to hospital discharge utilized are: prepregnancy BMI (defined above; obesity further categorized 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; 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 post-graduation). Smoking was evaluated based on smoking prior to pregnancy versus in the 3rd trimester (for each time point: non-smoker/stopped smoking, <10 cigarettes per day [cig/d], ≥10cig/d), categorized as: non-smoker at both time points; <10cig/d, stopped; ≥10cig/d, stopped; ≥10cig/d, reduced to <10cig/d; <10cig/d, maintained at <10cig/d; ≥10cig/d, maintained at ≥10cig/d; increased smoking [combined groups of: non-smoker, increased to <10cig/d; non-smoker, increased to ≥10cig/d; <10cig/d, increased to ≥10cig/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 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.[42] Prepregnancy conditions/pregnancy complications, obtained from chart abstraction and used for descriptive purposes, included diabetes in pregnancy (no; diet controlled; insulin controlled) and preexisting hypertension.

Statistical analysis

To describe the GWG profile of our cohort, for both survey years combined and individually, mean GWG (with standard deviations [SD]) 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% confidence intervals [CIs]) between categories of maternal characteristics, with a mean GWG difference of >1kg considered clinically significant. Similarly, adjusted polytomous logistic regression models were used to examine the association between maternal characteristics and GWG adequacy (adjusted odds ratio [aOR], 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 (meters),

GA at birth (days; linear models only, as GA at birth accounted for in definition of GWG adequacy), and survey year. The prepregnancy conditions/pregnancy complications (diabetes in pregnancy; preexisting 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 6-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 analytic 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 prepregnancy BMI (1%), employment during pregnancy (1%), education (1%), smoking status (1%), and diabetes (1%; not included in multivariable models).

We used SAS software version 9.4 for Windows (SAS Institute Inc., Cary, NC) for statistical analyses.

Patient and public involvement

A network representing French user associations on questions related to pregnancy, childbirth and infancy were 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 13.0kg (SD 5.6; Table 2), decreasing from 13.2kg (SD 5.6) in 2010 to 12.7kg (SD 5.7) in 2016 (eTable 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 were normal weight BMI entering pregnancy, 30% smoked either before or during pregnancy, 2.0% had preexisting hypertension, and 8.5% had diabetes in pregnancy. Compared to women excluded due to missing or implausible GWG, women included in our analytic sample were more likely to be primiparous, have a lower prepregnancy BMI, have modified their smoking habits during pregnancy, and have characteristics indicative of higher socio-economic status (eTable 2).

In unadjusted analysis, clinically significant differences (>1kg) 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 (11.1kg, SD 6.5 among women with insulin controlled and 10.2kg, SD 7.0 among women with diet controlled diabetes to 13.2kg, SD 5.5 among women without diabetes during pregnancy) or preexisting hypertension (11.7kg, SD 7.3 to 13.0kg, SD 5.6 among women without preexisting hypertension). In adjusted models, clinically significant differences in mean GWG persisted for maternal prepregnancy 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 prepregnancy 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 prepregnancy 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 to 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 prepregnancy 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 multi-national meta-analyses (LifeCycle [Europe, North America]: 21.5% insufficient, 42.0% excessive;[43] Goldstein et al. [Europe, United States, and Asia]: 23% insufficient, 47% excessive[7]). Examining GWG by BMI class, our findings (inverse relationship between prepregnancy 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 prepregnancy 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 (13.8kg, 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 (i.e., 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 the French study results may be attributed to differences in study design (retrospective versus prospective; nationally-representative versus 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 prepregnancy 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, and 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 physiologic changes to the metabolism and central nervous system resulting in increased appetite and the behavioral 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 (e.g., 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 (e.g., 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 to multiparas, a recent multi-national 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 United States 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 United States 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 United States[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 United States and Romania,[16,21,24] in line with our results. Given the 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 upon 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 (e.g., 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 cohort were consistent with our main analyses (data not reported), providing further evidence that biases due to GA at birth were minimized. 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 was self-reported and collected retrospectively. Specifically, self-reported prepregnancy 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 standardized 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 was 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 prepregnancy BMI, continuing or quitting smoking in pregnancy, and lower socioeconomic status were associated with not achieving GWG recommendations. To promote adequate GWG and optimize 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 United States and within BMI obesity classes is needed.

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Supplementary materials

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)

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)

Footnotes

Patient consent for publication: Not required

Ethics approval: Each survey cycle was approved by the National Council on Statistical Information (Comité du Label; 2016 approval number 2016X703SA), the French Commission on Information Technology and Liberties ([CNIL]; 2016 registration number 915197), and the Inserm ethics committee (2016 approval IRB00003888 no. 14-191).

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

	IOM recommendations/assumptions for GWG at 40 weeks gestation			Conversion to proportions of GWG achieved	
BMI[b]	1st trimester GWG (kg)	Rate of GWG (kg/week)	Recommended range (kg)	Expected GWG at 40 weeks	Recommended *range of proportion* of GWG
Underweight (<18.5)	2	0.51	12.5-18	15.77	0.79-1.14
Normal weight (18.5-24.9)	2	0.42	11.5-16	13.34	0.86-1.20
Overweight (25-29.9)	1	0.28	7.0-11.5	8.56	0.81-1.34
Obese (≥30)	0.5	0.22	5.0-9.0	6.44	0.78-1.41

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

[a]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*=13.34kg = (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 to *ranges of proportions* for her BMI group
   GWG adequacy classified as:
   - *Insufficient*: below lower bound
   - *Adequate:* within recommended range
   - *Excessive:* above upper bound

[b]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30

Table 2. Nationally-representative estimates of GWG and GWG adequacy[a] in France (French National Perinatal Survey 2010 and 2016; N=24850)

	n (%)	**GWG (kg)** mean (SD)	**Insufficient GWG** n (%)	**Adequate GWG** n (%)	**Excessive GWG** n (%)
Overall	24850	13.0 (5.6)	6606 (26.8)	9106 (37.0)	8892 (36.1)
BMI[b]					
Underweight	1960 (8.0)	13.9 (4.8)	762 (38.9)	785 (40.1)	411 (21.0)
Normal weight	15506 (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)

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;[38,39] 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 [≥40])[37]

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

	n (%)	GWG (kg) mean (SD)	Adjusted[a] difference in GWG (kg) diff (95% CI)
BMI[b]			
Underweight	1960 (8.0)	13.9 (4.8)	0.0 (-0.3, 0.3)
Normal weight	15506 (62.9)	13.8 (4.8)	reference
Overweight	4545 (18.4)	12.2 (6.0)	**-1.6 (-1.8, -1.4)**
Obese	2625 (10.7)	8.6 (7.4)	**-5.1 (-5.4, -4.8)**
Parity			
Multiparous	14061 (56.7)	12.4 (5.6)	reference
Primiparous	10722 (43.3)	13.7 (5.6)	0.7 (0.5, 0.8)
Age			
<25 years	3716 (15.0)	13.4 (6.3)	-0.0 (-0.3, 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, 0.3)
≥35 years	4918 (19.8)	12.5 (5.5)	-0.0 (-0.3, 0.2)
Country or region of birth			
France	20398 (82.2)	13.2 (5.5)	reference
Europe	957 (3.9)	13.0 (5.7)	0.3 (-0.1, 0.8)
Northern Africa	1720 (6.9)	12.1 (6.1)	-0.2 (-0.6, 0.2)
Sub-Saharan Africa	1024 (4.1)	11.2 (6.8)	-0.6 (-1.0, -0.1)
Other	719 (2.9)	12.5 (5.2)	0.0 (-0.5, 0.6)
Employment during pregnancy			
None	7089 (28.7)	12.3 (6.4)	0.1 (-0.2, 0.3)
Stopped working during pregnancy			
Before 14+0 wks gestation	1595 (6.5)	13.8 (6.3)	**1.2 (0.8, 1.5)**
14+0 to 27+6 wks gestation	6701 (27.1)	13.5 (5.5)	0.6 (0.4, 0.9)
28+0 to 31+6 wks gestation	4243 (17.2)	13.2 (4.9)	0.3 (-0.0, 0.5)
Unknown stop point	4743 (19.2)	12.8 (5.6)	0.1 (-0.7, 0.9)
Continued working to ≥32 wks 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, 1.0)
High school	9157 (37.1)	13.1 (6.3)	0.8 (0.6, 1.1)
1-2 years post-graduation	5086 (20.6)	13.2 (5.3)	0.6 (0.4, 0.9)
3-4 years post-graduation	4466 (18.1)	13.0 (4.9)	0.2 (-0.1, 0.5)
≥5 years post-graduation	3798 (15.4)	12.9 (4.5)	reference
Social deprivation[c]			
No	20424 (82.2)	13.1 (5.4)	reference
Yes	4414 (17.8)	12.5 (6.6)	-0.1 (-0.3, 0.1)
Smoking habits before, during pregnancy			
Non smoker	17216 (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, 1.8)**
≥10 cig/d, stopped	1402 (5.7)	16.2 (5.9)	**3.3 (2.9, 3.7)**
≥10 cig/d, <10 cig/d	2185 (8.9)	14.0 (6.2)	**1.3 (0.9, 1.6)**

Maintained smoking level in pregnancy			
<10 cig/d, <10 cig/d	845 (3.4)	13.4 (6.4)	0.9 (0.4, 1.4)
≥10 cig/d, ≥10 cig/d	1081 (4.4)	12.4 (6.5)	0.1 (-0.4, 0.5)
Increased smoking in pregnancy[d]	47 (0.2)	13.6 (5.4)	1.1 (-0.9, 3.2)
Insufficient care[e]			
No	23515 (94.7)	13.1 (5.6)	reference
Yes	1328 (5.3)	11.5 (6.4)	-0.9 (-1.2, -0.6)

Abbreviations: GWG= gestational weight gain; SD= standard deviation; CI= confidence interval; BMI= body mass index; cig/d= cigarettes per day; GA= gestational age

[a]Estimated using adjusted linear regression models; adjusted on all covariates in table, survey year, GA at birth, and mother's height

[b]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30[37]

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

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

[e]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 birthy 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

BOLD: clinically (>1kg) and statistically significant mean difference

Table 4. Associations between maternal characteristics and insufficient or excessive GWG[a] in multivariable logistic regression models (French National Perinatal Survey 2010 and 2016; N=23931)

	Insufficient GWG aOR[b] (95% CI)	**Excessive GWG** aOR[b] (95% CI)
BMI[c]		
Underweight	**1.4 (1.2, 1.5)**	**0.7 (0.6, 0.8)**
Normal weight	reference	reference
Overweight	**0.7 (0.6, 0.8)**	**2.8 (2.6, 3.1)**
Obese	**1.5 (1.4, 1.7)**	**3.3 (2.9, 3.6)**
Primiparity (versus multiparous)	**0.9 (0.9, 1.0)**	**1.2 (1.2, 1.3)**
Age		
<25 years	1.1 (1.0, 1.2)	1.0 (0.9, 1.1)
25-29 years	reference	reference
30-34 years	1.0 (0.9, 1.1)	1.0 (0.9, 1.1)
≥35 years	1.0 (0.9, 1.1)	0.9 (0.9, 1.0)
Country or region of birth (versus France)		
Europe	0.9 (0.8, 1.1)	1.1 (0.9, 1.3)
Northern Africa	1.1 (1.0, 1.3)	1.1 (1.0, 1.3)
Sub-Saharan Africa	**1.2 (1.0, 1.5)**	1.1 (0.9, 1.3)
Other	1.0 (0.8, 1.2)	1.1 (0.9, 1.3)
Employment during pregnancy		
None	**1.2 (1.0, 1.3)**	**1.2 (1.1, 1.3)**
Stopped working during pregnancy		
Before 14+0 wks gestation	1.0 (0.8, 1.1)	**1.6 (1.4, 1.8)**
14+0 to 27+6 wks gestation	0.9 (0.8, 1.0)	**1.2 (1.1, 1.4)**
28+0 to 31+6 wks gestation	0.9 (0.8, 1.0)	1.1 (1.0, 1.2)
Unknown stop point	1.1 (0.8, 1.4)	1.0 (0.8, 1.4)
Continued working to ≥32 wks gestation	reference	reference
Education (versus ≥5 years post-graduation)		
Less than high school	**1.2 (1.0, 1.4)**	**1.5 (1.3, 1.7)**
High school	1.0 (0.9, 1.1)	**1.5 (1.3, 1.6)**
1-2 years post-graduation	0.9 (0.8, 1.0)	**1.3 (1.2, 1.5)**
3-4 years post-graduation	1.0 (0.9, 1.1)	1.1 (1.0, 1.2)
Social deprivation[d]	1.1 (1.0, 1.2)	1.0 (0.9, 1.1)
Smoking habits before, during pregnancy (versus non-smokers)		
Decreased smoking in pregnancy		
<10 cig/d, stopped	**0.7 (0.6, 0.8)**	**1.4 (1.3, 1.6)**
≥10 cig/d, stopped	**0.6 (0.5, 0.7)**	**2.6 (2.3, 2.9)**
≥10 cig/d, <10 cig/d	0.9 (0.8, 1.0)	**1.5 (1.4, 1.7)**
Maintained smoking level in pregnancy		
<10 cig/d, <10 cig/d	1.1 (0.9, 1.3)	**1.5 (1.3, 1.8)**
≥10 cig/d, ≥10 cig/d	1.2 (1.0, 1.4)	**1.2 (1.0, 1.4)**
Increased smoking in pregnancy[e]	0.7 (0.3, 1.5)	1.4 (0.7, 2.7)
Insufficient care[f]	**1.2 (1.1, 1.4)**	0.9 (0.7, 1.0)

Abbreviations: GWG= gestational weight gain; aOR= adjusted odds ratio; CI= confidence interval; BMI= body mass index; cig/d= cigarettes per day; IOM= Institute of Medicine; GA= gestational age

[a]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

[b]Estimated using polytomous logistic regression models; adjusted on all covariates in table, survey year, and mother's height

[c]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese: ≥30[37]

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

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

[f]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

BOLD: statistically significant association (does not cross null)

Table 5. Association between maternal prepregnancy BMI[a] and GWG and GWG adequacy,[b] accounting for obesity classes I-III in adjusted regression models[c] (French National Perinatal Survey 2010 and 2016)

	N	GWG (kg) mean (SD)	Adjusted difference in GWG (kg) diff (95% CI)	Insufficient GWG aOR[b] (95% CI)	Excessive GWG aOR[b] (95% CI)
Underweight	1960	13.9 (4.8)	0.0 (-0.3, 0.3)	**1.4 (1.2, 1.5)**	**0.7 (0.6, 0.8)**
Normal weight	15506	13.8 (4.8)	reference	reference	reference
Overweight	4545	12.2 (6.0)	**-1.6 (-1.8, -1.4)**	**0.7 (0.6, 0.8)**	**2.8 (2.6, 3.1)**
Obese class I	1802	9.8 (6.7)	**-3.9 (-4.3, -3.6)**	**1.2 (1.0, 1.4)**	**3.8 (3.4, 4.3)**
Obese class II	589	7.0 (7.7)	**-6.7 (-7.3, -6.2)**	**1.9 (1.5, 2.4)**	**2.4 (2.0, 3.0)**
Obese class III	234	3.6 (8.3)	**-10.2 (-11.1, -9.3)**	**3.4 (2.4, 4.7)**	1.3 (0.9, 2.0)

Abbreviations: BMI= body mass index; GWG= gestational weight gain; SD= standard deviation; aOR= adjusted odds ratio; CI= confidence interval; IOM= Institute of Medicine; GA= gestational age at birth

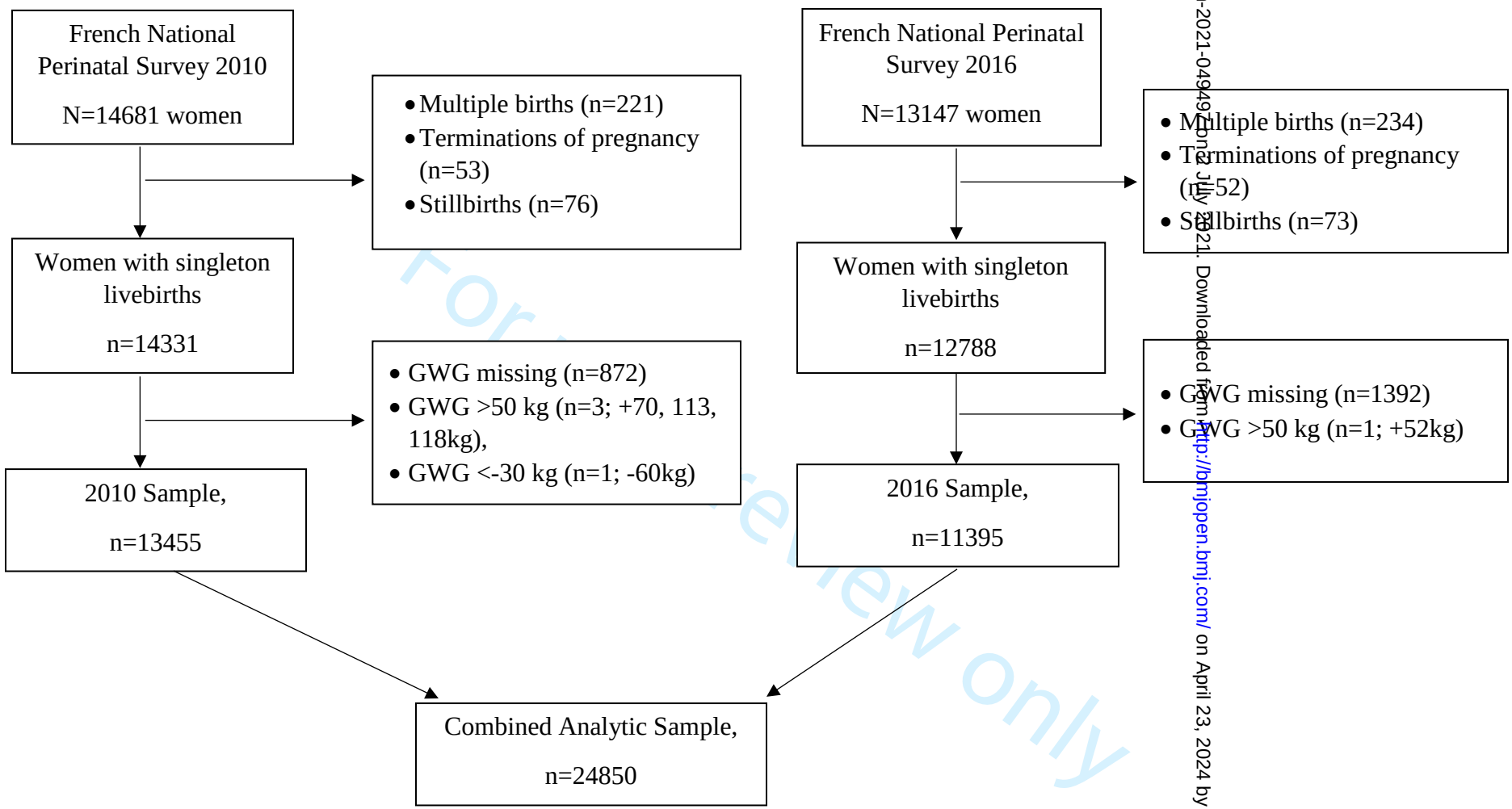
[a]BMI (kg/m^2): underweight: <18.5; normal weight: 18.5-24.9; overweight: 25-29.9; obese class I: 30-34.9; obese class II: 35-39.9; obese class III: ≥40[37]

[b]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

[c]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)

Figure legends

Figure 1: Participant flow chart



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 [≥40])[4]

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

References

1. Institute of Medicine. Weight gain during pregnancy: Reexamining the guidelines. 2009:1-13.
2. Bodnar LM, Siega-Riz AM, Simhan HN, Himes KP, Abrams B. Severe obesity, gestational weight gain, and adverse birth outcomes. *American Journal of Clinical Nutrition*. 2010;91(6):1642-1648.
3. Liu J, Gallagher AE, Carta CM, Torres ME, Moran R, Wilcox S. Racial differences in gestational weight gain and pregnancy-related hypertension. *Annals of Epidemiology*. 2014;24(6):441-447.
4. World Health Organization. Obesity: preventing and managing the global epidemic: report of a WHO consultation. Geneva, Switzerland: WHO Technical Report Series; 2000. Report No: 894.

STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1, 2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any pre-specified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5-6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5-6
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5-6
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	6-9
Bias	9	Describe any efforts to address potential sources of bias	6-7; 9-10
Study size	10	Explain how the study size was arrived at	5-6; Fig 1
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	n/a
		(*c*) Explain how missing data were addressed	10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	n/a

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		€ Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	5-6; Figure 1
		(b) Give reasons for non-participation at each stage	n/a
		© Consider use of a flow diagram	Figure 1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11; Table 2-3; eTable 1
		(b) Indicate number of participants with missing data for each variable of interest	10; 16
		© *Cohort study*—Summarise follow-up time (eg, average and total amount)	n/a
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	n/a
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	n/a
		Cross-sectional study—Report numbers of outcome events or summary measures	10-11; Table 2-3; eTable 1
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12; Tables 3-4
		(*b*) Report category boundaries when continuous variables were categorized	8; Tables 3-4
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12; Table 5
Discussion			
Key results	18	Summarise key results with reference to study objectives	12-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	15-16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	18

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.