Pregnancy outcomes related to gestational weight gain in women defined by their body mass index, parity, height, and smoking status

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ABSTRACT
Background: Recommendations for gestational weight gain (GWG) account for a woman’s prepregnancy body mass index (BMI), but other factors may be important.

Objectives: The objectives were to investigate whether, within BMI categories, the GWG with the lowest risks to mother and infant varied with parity and to describe these risks in short (<160 cm), young (<20 y), and smoking women.

Design: Of 27,030 primiparous and 31,407 multiparous women with term births within the Danish National Birth Cohort, self-reported GWG was divided into 6 categories (<5, 5–9, 10–15, 16–19, 20–24, and ≥25 kg). Population-based registers provided information about birth outcomes. GWG-specific absolute adjusted risks for emergency cesarean delivery, birth of a small-for-gestational-age (SGA) or large-for-gestational-age (LGA) infant, and postpartum (6 mo) weight retention (PPWR) were compared across different types of women.

Results: The risk of SGA decreased with increasing GWG in both parity groups, but SGA risk <10% was reached at 2–3 GWG categories lower than between primiparae. An excess risk of LGA was present only in obese primiparae and multiparae, but the PPWR risk increased with increasing GWG irrespective of BMI and parity. Young primiparae had better outcomes than other primiparae. Short women had a higher risk of emergency cesarean delivery that varied minimally with GWG. Smokers had a higher SGA risk and had a PPWR risk similar to that of nonsmokers.

Conclusions: The tradeoff in risk between mother and infant is varied among subgroups of women—young adolescents (≤16 y), black women, and short women (<157 cm)—because these characteristics may modify the association between gestational weight gain (GWG) and the outcome of pregnancy.

INTRODUCTION

Recommendations for weight gain during pregnancy have changed from a single target for all women (1) to different targets, depending on a woman’s prepregnant body mass index (BMI). In the most recent version, developed by the Institute of Medicine (IOM) in 1990 (2), recommendations were made for specific subgroups of women—young adolescents (≤16 y), black women, and short women (<157 cm)—because these characteristics may modify the association between gestational weight gain (GWG) and the outcome of pregnancy.

In a systematic review of the data on GWG and the outcome of pregnancy published since 1990, Viswanathan et al (3) found that there was “moderate evidence of the [independent] effects of age and parity, and weak evidence, largely because of insufficient data, on the effect of race” on the outcome of pregnancy. Relatively few studies had considered age as an effect modifier of GWG on outcome, and those that did generally categorized the younger women as those <20 y of age. Older maternal age was associated with increased risk of cesarean delivery (4, 5) and the birth of either a smaller or a larger infant (6, 7) but not with higher postpartum weight retention (8, 9). In the few studies on parity and outcomes of pregnancy, primiparity was associated with a higher risk of cesarean delivery (10, 11) and low birth weight (12), whereas multiparity was associated with a higher risk of giving birth to a larger infant (13), a lower risk of a smaller infant (10), and no excess risk of weight retention (14). Maternal height was not considered in this review (3), although it was recently shown that GWG differs significantly across height groups among women with the same BMI (15). Furthermore, short women who give birth to large infants may have a higher risk of birth injury (16). The systematic review (3) did not include maternal smoking, which has a complex relation with prepregnant BMI, GWG, and several adverse outcomes of pregnancy (17–20).

In the analyses reported here, we used data from the Danish National Birth Cohort to investigate whether the point at which adverse risks to mother and infant are minimal varied among primiparous and multiparous women of similar BMI. Furthermore, we described how these risks varied among women who were young (<20 y), short (<160 cm), or smokers. In our recent report (21), GWG was closely associated with emergency ce-
sarean delivery, the birth of a small-for-gestational-age (SGA) or large-for-gestational-age (LGA) infant, and postpartum weight retention, and these outcomes were also examined here. We examined 4 BMI groups, from underweight to obese, with GWG in 6 categories to capture associations at the extremes of the range of GWG.

SUBJECTS AND METHODS

Subjects
From the Danish National Birth Cohort (DNBC), we had information on 60,892 live-born, full-term singleton (≥37 wk of gestation) infants whose mothers had participated in 2 telephone interviews: a pregnancy interview at ≈16 wk of gestation and a postpartum interview 6 mo after birth. They provided information about prepregnancy BMI, GWG, and postpartum weight retention. A more detailed description of the study population and the data collection was published recently (21).

In the present study, we included 71 pregnancies in which the woman was <18 y of age, which was an exclusion criterion in the previous study. Furthermore, we excluded pregnancies complicated by preeclampsia (n = 1118) and gestational diabetes (n = 690). As a result, we had 59,147 pregnancies of 56,090 women in the final study population. All participants provided written consent. The study was approved by all of the scientific ethics committees in Denmark and by the Danish Data Protection Board.

Exposure variables
The main exposures were prepregnancy BMI (kg/m²) and GWG. In the pregnancy interview, the women reported their prepregnancy weight and height, which were used to calculate their prepregnancy BMI and categorize them according to the World’s Health Organization’s definitions of underweight (BMI < 18.5), normal weight (18.5 ≤ BMI < 25), overweight (25 ≤ BMI < 30), and obese (BMI ≥ 30) (22). Gestational weight gain was based on information from the postpartum interview 6 mo after birth. At this time, the woman was asked “How much (in kg) was your total weight gain in pregnancy?” Her response was divided into 6 categories: <5, 5–9, 10–15, 16–19, 20–24, and ≥25 kg. We used as reference the 10–15-kg category, which was associated with minimum infant mortality in other populations (2).

From the pregnancy interview, we also used information about the mother’s age at conception and parity, smoking during pregnancy, alcohol intake and physical exercise during pregnancy, and social status defined by education and occupation. Information about duration of breastfeeding was reported by the women in the postpartum interview. The categorization of these variables is described in greater detail elsewhere (21) except for smoking, which was categorized as yes or no in the present study.

Outcomes
Pregnancy outcomes used in this study included birth weight standardized by gestational age according to the reference curve of Marsal et al (23). Standardized birth weight was dichotomized into either an SGA infant (z score < 10th percentile) or an LGA infant (z score > 90th percentile). Emergency cesarean deliveries were identified in the National Hospital Discharge Register and were defined as a cesarean delivery carried out when the woman was in labor. Postpartum weight retention was defined as a weight difference of ≥5 kg between the woman’s prepregnancy weight and her weight 6 mo after birth as reported in the postpartum interview.

Statistical methods
In our previous study (21), we found that being multiparous was strongly associated with a decreased risk of SGA [adjusted odds ratio (OR): 0.4; 95% CI: 0.4, 0.4], increased risk of LGA (adjusted OR: 2.3; 95% CI: 2.2, 2.4), and decreased risk of emergency cesarean delivery (adjusted OR: 0.3; 95% CI: 0.3, 0.3), but not with postpartum weight retention (adjusted OR: 1.1; 95% CI: 1.0, 1.1). On the basis of these findings, we divided the study population into primiparous (n = 27,030) and multiparous (n = 32,117) women to investigate the associations between BMI, GWG, and selected pregnancy outcomes within each of these strata.

We generated a BMI- and GWG-specific variable by cross-classifying BMI group (4 categories) and GWG group (6 categories). Few underweight women reported a low GWG; therefore, for this group, the 2 lowest categories were combined into 1 category, which was defined as a gain <10 kg. Thus, this BMI- and GWG-specific variable consisted of 23 categories. Normal-weight women with a GWG of 10 to 15 kg were used as reference.

To estimate the independent associations of maternal age, height, and smoking behavior with the pregnancy outcomes of interest within each parity group, the BMI- and GWG-specific variable and the covariates age, height, and smoking were mutually adjusted in multiple logistic regression models. In these models, we also adjusted for alcohol consumption and exercise in pregnancy, social status, and gestational age at delivery in days such that the same adjustment was applied to all BMI and GWG categories. In the analysis of postpartum weight retention, duration of breastfeeding was added to the model. In the analysis of emergency cesarean delivery, we excluded women who had a cesarean delivery before labor (1485 primiparous and 2429 multiparous women). The hypothesis of no interaction between the effect of the separate BMI and GWG variables on the outcomes was tested with Wald’s test.

We used the calculated odds ratios from the models above to compute absolute adjusted risks for pregnancy outcomes according to each category within the BMI- and GWG-specific variable (which produced 23 different absolute adjusted risks for each pregnancy outcome). This was done for 4 different sets of characteristics among primiparous women and 3 different sets among multiparous women, which created a total of 7 different types of women as follows. First, for both primiparous and multiparous, we defined “a reference woman” who was 25–29 y of age, 1.60–1.69 m, and did not smoke or consume alcohol during pregnancy. This “unexposed woman” performed a moderate amount of exercise during pregnancy, was of high social status, and had a gestational length of 280 d. For postpartum weight retention, she breastfed <14 wk. In both groups, the same characteristics applied for “a short woman,” only she was <1.60 m tall. “A smoking woman” was also defined as a reference woman, only she was a smoker. Among primiparous women we
also defined “a young woman,” who was similar to the reference woman, only she was <20 y of age. Because 704 multiparous women provided more than one birth within the multiparous subpopulation, we repeated the analysis after including only one birth from each woman within this group. We used STATA software (version 9.1 Special Edition; Stata Corp, College Station, TX) for all statistical analyses.

RESULTS

Parity

Overall, primiparous women gained more weight during pregnancy than multiparous women (mean ± SD: 15.7 ± 5.9 compared with 14.6 ± 5.7 kg; P < 0.0001). The clear trend toward lower GWG with increasing BMI was especially apparent among multiparous women, where up to 20% of overweight and 45% of obese women gained <10 kg (compared with 14% and 37%, respectively, among primiparous women) (Table 1). In both parity groups, the mean gain in women with GWG values <5 kg decreased with increasing BMI. On average, obese women in this category lost 2 kg during pregnancy.

Absolute adjusted risks for pregnancy outcomes in primiparous and multiparous women are shown in Figure 1, A and B. (The complete set of results from the logistic regression analyses is available in Tables S1 and S2, and additional figures in color, including tables with all absolute risks, are available as Figure S1a-b under “Supplemental data” in the online issue.) In both parity groups, the risk of delivering an SGA infant decreased with increasing weight gain, but the absolute risk difference when moving from low to high GWG was substantially higher in primiparous. Among primiparous, lower GWG was associated with a risk of SGA above the 10% that would, by definition, be expected to occur in the population, especially among underweight and normal-weight women. Thus, in primiparae, an absolute risk at or <10% was first observed with a GWG >25 kg in underweight women, a GWG of 16–19 kg in normal-weight women, and a GWG of 10–15 kg in overweight women. Obese primiparae did not have any notable excess risk of SGA, even with low GWG.

Among underweight and normal-weight multiparae, an absolute risk of SGA at or below 10% was reached at 2–3 GWG categories lower than among primiparae. In overweight and obese multiparae, the absolute risk was far below 10%, even in the lowest gain categories, and it decreased little with further gain.

In both parity groups, the absolute risk of delivering an LGA infant increased with increasing gain, but the level of the absolute risk was much higher in multiparae than in primiparae. This was especially the case in the higher GWG categories, in which multiparous women had nearly twice the risk of LGA as primiparous women. With a gain of 16–19 kg, obese multiparae reached their highest risk of LGA (36%), and increasing gain beyond this point was not associated with further increase in risk of LGA. For obese primiparae, the risk of having an LGA infant continued to increase with increasing gain, reaching almost 30% for GWG values ≥25 kg. In both parity groups, the absolute risk of emergency cesarean delivery only increased slightly with increasing GWG, but primiparae had at least twice the risk of emergency cesarean delivery as multiparae, irrespective of BMI. Postpartum weight retention showed the same strong association with increasing gain in primiparae and multiparae.

Short stature, smoking, and young age

For both primiparous and multiparous women, we examined the change in risk of the 4 selected outcomes for women who

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Gestational weight gain (GWG) across prepregnancy BMI and weight-gain categories¹</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>No. of subjects</td>
</tr>
<tr>
<td>Primiparous women</td>
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<tr>
<td>Total</td>
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<tr>
<td>GWG</td>
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<tr>
<td>&lt;5 kg</td>
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</tr>
<tr>
<td>5–9 kg</td>
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<td>11,578</td>
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<tr>
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<tr>
<td>20–24 kg</td>
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<tr>
<td>≥25 kg</td>
<td>2369</td>
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<tr>
<td>Multiparous women</td>
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<tr>
<td>Total</td>
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<tr>
<td>GWG</td>
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<tr>
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<td>20–24 kg</td>
<td>4196</td>
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<tr>
<td>≥25 kg</td>
<td>1894</td>
</tr>
</tbody>
</table>

¹ Percentages in the first row are row percentages; all others are column percentages. n = 1180 and 1447 underweight, n = 19,141 and 21,641 normal-weight, n = 4881 and 6491 overweight, and n = 1828 and 2538 obese primiparous and multiparous women, respectively.

² GWG categories <5 kg and 5–9 kg were combined to <10 kg because of few cases.
were short in stature, young (< 20 y old; primiparae only), or smoked during pregnancy (Figure 2, A–D). (Additional figures in color, including tables with all absolute risks, are available as Figure S2a–d under “Supplemental data” in the online issue.) Overall, short women had higher risks of SGA and lower risks of LGA than did women of normal height irrespective of gain. Risk of emergency cesarean delivery was consistently highest among short primiparae than among all other types of women, especially in obese women in whom the highest increase across GWG categories was observed (from 26% to 42%). Although the same risk in short multiparae was less than half of that observed in primiparae, it was still twice the risk of multiparous women with normal height.

Smoking primiparae had a remarkably high risk of SGA, which reached a high of 67% in underweight women with weight gains <10 kg and was never below the expected 10% in any BMI or GWG group. The risk of LGA was low in smokers, but multiparous smokers above the normal-weight range and with high gains had a modest excess risk, which, however, was negligible compared with the high values observed in unexposed multiparae—the only group with a significant excess risk of LGA. Smokers had the same risk of emergency cesarean delivery and postpartum weight retention as nonsmokers.

Across all BMI groups, young primiparae had lower risks of SGA, LGA, and emergency cesarean delivery than other primiparae. They did, however, have a higher risk of postpartum weight retention than other primiparae, especially with high gains.

Associations related to GWG across BMI groups

For all outcomes, as BMI increased, we observed a change in the sensitivity to changes in GWG, ie, in the slopes related to GWG (Figures 2, A–D). This change in sensitivity was statistically significant for all outcomes, except for emergency cesarean delivery in primiparae. Among underweight women (Figure 2A), the risk of SGA was high but decreased steeply with increasing gain. As expected, the pattern for LGA was the opposite, but the slopes for SGA were much steeper than the slopes for LGA. Emergency cesarean delivery was only slightly affected by increasing GWG, whereas postpartum weight retention increased substantially with increasing GWG. We observed the same patterns among normal-weight women (Figure 2B). However, compared with underweight women, the slopes for SGA decreased slightly, whereas the slopes for LGA increased.

Among overweight women (Figure 2C), the slopes for SGA decreased further, whereas the slopes for LGA and emergency cesarean delivery increased. Thus, for these 3 outcomes, the slopes related to GWG seemed to be similar. In the heaviest women (Figure 2D), the slopes for LGA and emergency cesarean delivery increased further compared with the other BMI groups and were steeper than the slopes for SGA, which had decreased further. Risk of postpartum weight retention still increased steeply with increasing GWG, but the slopes for obese women were slightly reduced compared with slopes for women of lower weight. We repeated all analyses in multiparous women after excluding the 704 women who contributed more than one birth to this group and had results similar to those presented.

DISCUSSION

This study extended our previous investigation on GWG and pregnancy outcomes and showed that characteristics in addition to prepregnancy BMI were associated with a woman’s risk of adverse pregnancy outcomes. The most important of these characteristics was parity. Primiparae gained more weight during pregnancy than multiparae. Although the risk of SGA was consistently higher in primiparae than in multiparae with similar
gain, the steeply increasing risk of postpartum weight retention with increasing gain was independent of parity. At the same time, a considerable excess risk of LGA was only present in obese primiparae and multiparous women. These findings suggest that the most favorable tradeoff between maternal and infant health, for the variables we studied, was reached at a lower GWG among multiparous than primiparous women. As a result, within a given prepregnancy BMI category, multiparous women could potentially be advised to gain less weight than primiparous women.

Use of the data from the DNBC made it possible to simultaneously consider major outcomes that were frequent in the population and for which a causal relation to GWG seemed plausible. For all subgroups of women, the sensitivity of the absolute risks to changes in GWG changed across BMI groups, thereby confirming prior research (24–28)—including our own work (21)—that has supported the importance of considering a woman’s prepregnancy BMI. It is also well-known that primiparous women have smaller infants (10, 12) and gain more
weight than do multiparous women, as was observed in the present study. It is an important new finding, however, that their risk of postpartum weight retention was similar to that of multiparous women, which indicates that the point of tradeoff between mother and infant differs between primiparous and multiparous women. In our interpretation of the results, we placed great emphasis on the risk of an SGA birth, for which we found an acceptable risk to be close to the expected 10%, at least among women of normal height.

In the 1990 IOM guidelines (2), it was suggested that young (<16 y old) adolescents should gain more weight to avoid having a SGA baby. The DNBC contained so few pregnancies to girls of this age that we were not able to replicate this analysis. However, we did have an adequate sample to study those <20 y of age and, in this group, we found no modification of the association between GWG and the outcomes we studied. This is probably because these adolescents, who had an average age of 18.4 y, had reached their full growth potential. The data did not support the idea, also included in the 1990 IOM guidelines (2), that short (<157 cm) women should gain at the lower end of the recommended range. Although we found a high risk of SGA in short women, this result should be interpreted with caution because a higher proportion of short women will naturally give birth to small babies. We also observed a high risk of emergency cesarean in short primiparae, which is probably related to pelvic size (16), because the risk did not vary much with GWG.

Smokers had a substantial excess risk of SGA, except for multiparous women with high prepregnant BMI values and high gains. However, they retained weight like nonsmokers. This is concordant with our understanding of the dual mechanisms by which smoking interferes with fetal growth, which is partly via poor nutrient transfer/placental dysfunction (29, 30), which can be addressed by additional GWG, and partly via direct toxicity of cigarette smoke (31), which is not ameliorated by additional GWG. Thus, smoking cessation remains the best way improve birth outcomes and reduce the risk of excessive postpartum weight retention among smokers.

The DNBC provided us with a large enough sample of pregnant women to permit us to study primiparae and multiparae separately. Regrettably, we did not have sufficient power to study the heaviest women and those at the youngest ages separately. We had complete linkage to hospital discharge records and were able to distinguish between planned and emergency cesarean deliveries, which is important because they are associated with different risks for complications. Studying emergency cesarean deliveries in multiparous women is difficult because women who have had a previous emergency cesarean delivery may have a planned cesarean in a subsequent pregnancy. This problem is not present among primiparous women.

Our study population was white as only 4% of the women were born outside Scandinavia. It seems reasonable to assume that the results may apply to other populations of European origin with a Western lifestyle. The generalizability of these findings to other racial-ethnic groups is unknown.

Information about BMI and gestational weight gain was self-reported and inevitably prone to some misclassification error. This problem would most likely lead to an underestimation of the associations, which we have examined in more detail elsewhere (21). The associations described here should be interpreted with caution, as we used observational data to study quite complex etiological patterns. Inasmuch as the causal links between the variables we studied are mainly unknown we cannot guarantee that that we may have included intermediate variables in the analyses. Also, some uncontrolled confounding is likely to remain even though we had more information about potential confounders than most other studies.

This study is the first to demonstrate that the point of tradeoff between mother and infant may be reached at lower GWG levels in multiparous than in primiparous, which may provide an attractive approach to reduce postpartum weight retention given the alarming prevalence of obesity in women of childbearing age (32). This novel finding bears confirmation by others before it should be used as a basis for different recommendations in these 2 groups. The results of this study suggest that differential guidelines for GWG are not needed for short (<160 cm) or young (<20 y old) women. However, specific guidelines for all of these population subgroups should be supported by results from experimental studies that confirm the potential benefits suggested by the associations observed here.

The authors’ responsibilities were as follows—EAN, KMR, and MV: conceived the study; EAN: prepared the data set for analysis; EAN and MV: conducted the data analysis; EAN and KMR: prepared the manuscript; MV, JLB, TIAS, and JO: critically revised the manuscript; and JO and TIAS: led the overall data acquisition of the DNBC. None of the authors had any conflict of interest to declare.

REFERENCES


