Determining optimal gestational weight gain in a multiethnic Asian population

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Abstract

Aim: To define the optimal gestational weight gain (GWG) for the multiethnic Singaporean population.

Methods: Data from 1529 live singleton deliveries was analyzed. A multinomial logistic regression analysis, with GWG as the predictor, was conducted to determine the lowest aggregated risk of a composite perinatal outcome, stratified by Asia-specific body mass index (BMI) categories. The composite perinatal outcome, based on a combination of delivery type (cesarean section [CS], vaginal delivery [VD]) and size for gestational age (small [SGA], appropriate [AGA], large [LGA]), had six categories: (i) VD with LGA; (ii) VD with SGA; (iii) CS with AGA; (iv) CS with SGA; (v) CS with LGA; (vi) and VD with AGA. The last was considered as the ‘normal’ reference category. In each BMI category, the GWG value corresponding to the lowest aggregated risk was defined as the optimal GWG, and the GWG values at which the aggregated risk did not exceed a 5% increase from the lowest aggregated risk were defined as the margins of the optimal GWG range.

Results: The optimal GWG by pre-pregnancy BMI category, was 19.5 kg (range, 12.9 to 23.9) for underweight, 13.7 kg (7.7 to 18.8) for normal weight, 7.9 kg (2.6 to 14.0) for overweight and 1.8 kg (−5.0 to 7.0) for obese.

Conclusion: The results of this study, the first to determine optimal GWG in the multiethnic Singaporean population, concur with the Institute of Medicine (IOM) guidelines in that GWG among Asian women who are heavier prior to pregnancy, especially those who are obese, should be lower. However, the optimal GWG for underweight and obese women was outside the IOM recommended range.

Keywords: cesarean section, pregnant women, Singapore, size for gestational age, weight gain.

Introduction

Pre-pregnancy maternal obesity and excessive gestational weight gain (GWG) have been linked to increased risk of gestational diabetes,1,2 pre-eclampsia,3 large for gestational age birthweight (LGA)4–6 and cesarean section (CS).7,8 Pre-pregnancy maternal underweight and insufficient GWG have been linked to small for gestational birth weight (SGA)9,10 and preterm delivery.11 Asian studies have also linked pre-pregnancy weight and GWG to various adverse perinatal outcomes.12,13

Gestational weight gain guidelines were first established by the US Institute of Medicine (IOM) in 199014
and were revised in 2009\textsuperscript{15} due to increasing obesity prevalence,\textsuperscript{16,17} higher maternal age at pregnancy and new knowledge regarding pregnancy. However, they may be of limited use in Asian populations because they are largely based upon studies of Caucasian women. Further, the World Health Organization (WHO) international body mass index (BMI) cut-off points defining pre-pregnancy BMI categories in the IOM guidelines are not directly applicable to Asians. Many Asian populations have a higher proportion of body fat\textsuperscript{18} and increased risk for cardiovascular diseases and diabetes at lower BMI levels\textsuperscript{19} than their Caucasian counterparts. Thus, the WHO recommends lower BMI cut-off points for defining overweight and obesity among Asian women.\textsuperscript{20} Also, studies have found different optimal GWG values for different Asian populations,\textsuperscript{21,22} emphasizing the importance of determining regional- or country-specific GWG guidelines. However, GWG guidelines for the multiethnic Asian population of Singapore are not available.

We aimed to determine the optimal GWG and its range, for each pre-pregnancy BMI category defined by the WHO Asian BMI classification, among Singaporean women. We do so by a quantitative risk assessment approach that assesses the GWG in each BMI category which minimizes the total risk associated with three adverse perinatal outcomes, namely, CS delivery, LGA and SGA.

**Methods**

**Study sample**

From January through April 2008, 4065 pregnant women delivered at KK Women’s and Children’s Hospital, the largest tertiary women’s and children’s hospital in Singapore, which accounts for approximately 12 000 of the 30 000 births per year in the country. Data for 2687 women of Chinese, Malay or Indian ethnicity who had live singleton births was extracted from the hospital’s medical records office. The analysis sample for this study comprised 1529 women who had their first antenatal visit in their first trimester, after excluding 1029 women who had their first antenatal visit after their first trimester and 129 women who had missing data on height, weight or parity. Compared to the women in the analysis sample, those excluded because of first antenatal visit after the first trimester were younger (30.3 ± 4.9 vs 28.1 ± 6.0 years) and of higher parity (1.9 ± 1.0 vs 2.1 ± 1.2). The study was approved with a waiver of informed consent by the Central Institutional Review Board, SingHealth, and was exempted from review by the Duke University Medical Center Institutional Review Board.

**Maternal anthropometry**

Maternal anthropometric measures were extracted from the medical records of the study participants. Height in meters was measured on standardized height measuring stations and weight in kilograms was measured on standardized digital weighing scales by trained patient care assistants in the KK Women’s and Children’s Hospital antenatal clinics. The earliest weight recorded in the first trimester (mean, 8.03 ± 1.93 weeks) was used as a proxy for pre-pregnancy weight, with the assumption that weight gain in the first trimester is negligible.\textsuperscript{23} This assumption has been made in previous studies of GWG.\textsuperscript{24} Thus, first trimester BMI (weight [kg]/height [m]²), as a proxy for pre-pregnancy BMI, was calculated using this weight and height. BMI (kg/m²) was classified using the WHO Asian BMI classification (underweight, <18.5; normal weight, 18.5 to <23; overweight, 23 to <27.5; obese: ≥27.5), based on guidelines from the Ministry of Health, Singapore,\textsuperscript{25} which in turn are adapted from the Asia-specific WHO public health action points along the continuum of BMI.\textsuperscript{20} GWG (kg) was calculated as the difference between the weight recorded at the antenatal visit nearest to the actual date of delivery (mean, 37.53 ± 2.53 weeks) and the weight recorded at the first antenatal visit. Gestational age (in weeks) was calculated from the expected date of delivery, which was derived from the ultrasound scan measurement of fetus crown–rump length during the first trimester or, if ultrasound findings were unavailable, from the date of the last menstrual period.

**Perinatal outcomes**

The perinatal outcomes used to determine optimal GWG (and the associated low and high margins of a range) were size for gestational age (SGA, appropriate for gestational age [AGA] and LGA) and type of delivery (CS delivery and vaginal delivery [VD]). Size for gestational age, rather than birthweight, was considered for the analysis so as to account for potential confounding by gestational age at delivery. For example, low birthweight neonates (<2500 g) were a heterogeneous group that comprised SGA neonates as well as AGA neonates delivered prematurely. Using the weight growth chart by Fenton,\textsuperscript{26} at a particular gestational age SGA was defined as a birthweight less than or equal to the 10th percentile of the weight for that gestational age while LGA was defined as more than or
equal to the 90th percentile of the weight for that gestational age. Type of delivery was considered because, while SGA and LGA represent the adverse perinatal outcomes most commonly associated with maternal pre-pregnancy BMI status and non-optimal GWG, CS delivery is an important immediate adverse perinatal outcome associated with maternal obesity. Pre-eclampsia and gestational diabetes were not considered as outcomes for the formulation of the IOM 2009 guidelines for GWG due to lack of sufficient evidence that inappropriate GWG is a cause of these conditions and not just a reflection of the disease; while we had information on these conditions, we also did not consider them as outcomes in our analysis for the same reason.

In most previous studies linking GWG with perinatal outcomes, the adverse outcomes of non-optimal size for gestational age and CS delivery have been studied independently even though the two are not mutually exclusive. A mother who has delivered vaginally may still have an SGA or LGA baby, and a mother who has delivered by CS may still have an AGA baby. Therefore, we deemed it more appropriate to analyze a composite outcome combining the two categorically different adverse outcome variables. We created a composite perinatal outcome variable based on combinations of delivery type (CS, VD) and size for gestational age (SGA, LGA, AGA), with six mutually exclusive and exhaustive categories: (i) VD with LGA; (ii) VD with SGA; (iii) CS with AGA; (iv) CS with SGA; (v) CS with LGA; and (vi) VD with AGA. The last category, comprising both of the ‘non-adverse’ outcomes (AGA and VD), was used as the ‘normal’ reference category in the logistic regression analysis.

**Statistical analysis**

All analyses were performed using SAS version 9.2 software. Generalized multinomial logistic regression analysis, controlling for ethnicity (Chinese, Malay and Indian), stratified by pre-pregnancy BMI category, was used to assess the association between the predictor GWG and the six-category composite perinatal outcome. The probability of occurrence of each of the six perinatal outcome categories was estimated as a function of GWG within each BMI stratum. Then, an aggregate (total) risk curve as a function of GWG was obtained for each BMI category by summing the probabilities of the five adverse outcome categories: (i) VD with LGA; (ii) VD with SGA; (iii) CS with AGA; (iv) CS with SGA; and (v) CS with LGA. The optimal GWG for a given BMI category was defined as the GWG corresponding to the lowest aggregated risk. A similar analytical approach has been used before for determining the optimal GWG in the German population, although that study considered only size for gestational age as the outcome. The GWG values at which the aggregated risk did not exceed a 5% increase from the lowest aggregated risk were defined as the margins of the optimal GWG range in each BMI category. In exploratory analyses, the optimal GWG values and range for each ethnicity (Chinese, Malay and Indian) were estimated in a similar fashion.

**Results**

Characteristics of the study participants are summarized in Table 1. Most gave birth when they were 25 to less than 30 years (31.3%) and 30 to less than 35 years (37%). The majority of the study participants were of Chinese ethnicity (62.7%), followed by Malay (23.4%) and Indian (13.9%). Of the 1529 women, 196 (12.8%) were underweight, 698 (45.6%) were of normal weight, 383 (25.1%) were overweight and 252 (16.5%) were obese at their first antenatal visit. Most participants (84.3%) delivered an AGA baby. Only 195 (12.8%)...
delivered an SGA baby and 45 (2.9%) delivered an LGA baby. Most of the women underwent VD delivery (67.4%). Table 2 presents the distribution of the composite perinatal outcome among the study participants. The most common combination was VD with AGA (69.7%), while the least common was CS with LGA (0.8%).

Table 3 presents the odds of the various adverse perinatal outcome categories, relative to the VD with AGA category for one unit increase in GWG, adjusting for ethnicity. Increase in GWG was associated with significantly higher odds of having an LGA baby delivered vaginally (odds ratio [OR], 1.13; 95% confidence interval [CI], 1.07–1.21) and of having an AGA baby delivered by CS (OR, 1.05; 95% CI, 1.02–1.08). It was also associated with significantly lower odds of having an SGA baby delivered vaginally (OR, 0.94; 95% CI, 0.90–0.97) or by CS (OR, 0.92; 95% CI, 0.86–0.98).

Figure 1 shows the risk of each of the adverse perinatal outcome categories and the total aggregated risk of an adverse outcome (an aggregation of all five adverse categories) according to GWG by the WHO Asian BMI categories. The lowest aggregated risk of an adverse outcome was 29.7% for underweight, 27.4% for normal weight, 30.3% for overweight and 32.3% for obese. The corresponding GWG values, representing the optimal GWG were 19.5, 13.7, 7.9 and 1.8 kg, respectively. These values along with the optimal GWG range and the IOM 2009 Guideline values for each BMI category, are given in Table 4. The estimated optimal GWG values and range for each BMI category for the three major ethnic groups in Singapore are presented in Table 5.

Discussion

Our analyses concur with current published work in that increasing GWG is associated with having an LGA baby and decreasing GWG is associated with having an SGA baby. As we hypothesized, the optimal GWG in this Asian population differs from that of the IOM 2009 guidelines,15 which are based primarily on data from Caucasian women.

Akin to the IOM 2009 guidelines, optimal GWG was higher for women who were in a lower BMI category and lower for women who were in a higher BMI category. However, notably in our analysis, underweight Singaporean Asian mothers may gain more gestational weight than the IOM 2009 guidelines recommend.

Table 2 Distribution of the composite perinatal outcome among the 1529 study participants

<table>
<thead>
<tr>
<th>Delivery type</th>
<th>Size for gestational age</th>
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<tbody>
<tr>
<td></td>
<td>SGA</td>
</tr>
<tr>
<td>CS</td>
<td>2.7 (41)†</td>
</tr>
<tr>
<td>VD</td>
<td>10.1 (154)</td>
</tr>
</tbody>
</table>

†The numbers in each cell reflect the % (n) with the particular delivery type/size for gestational age combination among the 1529 study participants. AGA, appropriate for gestational age; CS, cesarean section delivery; LGA, large for gestational age; SGA, small for gestational age; VD, vaginal delivery.

Table 3 Odds of each perinatal composite outcome relating to a one unit increase in gestational weight gain

<table>
<thead>
<tr>
<th>Outcome</th>
<th>OR (95% Wald confidence limit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VD with AGA</td>
<td>Reference</td>
</tr>
<tr>
<td>VD with LGA</td>
<td>1.13 (1.07–1.21)</td>
</tr>
<tr>
<td>VD with SGA</td>
<td>0.94 (0.90–0.97)</td>
</tr>
<tr>
<td>CS with LGA</td>
<td>1.08 (0.98–1.18)</td>
</tr>
<tr>
<td>CS with AGA</td>
<td>1.05 (1.02–1.08)</td>
</tr>
<tr>
<td>CS with SGA</td>
<td>0.92 (0.86–0.98)</td>
</tr>
</tbody>
</table>

AGA, appropriate for gestational age; CS, cesarean section delivery; LGA, large for gestational age; OR, odds ratio; SGA, small for gestational age; VD, vaginal delivery.

Table 4 Optimal GWG corresponding to the lowest sum of risk of adverse outcomes

<table>
<thead>
<tr>
<th>BMI category</th>
<th>Optimal GWG (kg)</th>
<th>IOM 2009 guidelines† (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight (&lt;18.5 kg/m²)</td>
<td>19.5 (12.9 to 23.9)‡</td>
<td>12.5 to 18</td>
</tr>
<tr>
<td>Normal (18.5 to &lt;23 kg/m²)</td>
<td>13.7 (7.7 to 18.8)</td>
<td>11.5 to 16</td>
</tr>
<tr>
<td>Overweight (23 to &lt;27.5 kg/m²)</td>
<td>7.9 (2.6 to 14.0)</td>
<td>7 to 11.5</td>
</tr>
<tr>
<td>Obese (≥27.5 kg/m²)</td>
<td>1.8 (~5.0 to 7.0)</td>
<td>5 to 9</td>
</tr>
</tbody>
</table>

†Institute of Medicine 2009 guidelines stratified by World Health Organization Body Mass Index classification. ‡Numbers in parenthesis represent the lower and upper margins of the GWG range for which aggregated risk of composite adverse outcome does not exceed a 5% increase from the lowest aggregated risk. BMI, body mass index; GWG, gestational weight gain; IOM, Institute of Medicine (US).
Figure 1 Risk of each adverse pregnancy outcome and of aggregated adverse pregnancy outcome according to gestational weight gain by World Health Organization Asian body mass index (BMI) categories. AGA, appropriate size for gestational age; CS, cesarean section; LGA, large size for gestational age; SGA, small size for gestational age; VD, vaginal delivery.
without increasing their risk of the perinatal outcomes considered while obese mothers are likely to benefit from gaining less than recommended by IOM. For obese women, our optimal GWG range suggested weight loss, of up to 5 kg. However, we are reluctant to endorse weight loss during the antenatal period given the lack of studies looking at the effects of weight loss in pregnancy. Several reasons may explain the differences in our GWG estimates relative to the IOM guidelines. First, our methodology for calculating optimal GWG differed from that used to establish the IOM 2009 guidelines. While we adopted a quantitative approach to determine the optimal GWG by combining the most commonly studied perinatal outcomes, birthweight relative to gestational age and type of delivery, as a single composite variable, the IOM guidelines were constructed by a committee based on range of GWG values from various large studies associated with lowest prevalence of the outcomes of greatest interest. These outcomes included cesarean delivery, postpartum weight retention, preterm birth, small or large for gestational age at birth, and childhood obesity. Second, the pre-pregnancy BMI cut-off points utilized in our study were based on the WHO Asian BMI categories, while the IOM 2009 guidelines were based on WHO international BMI cut-off points. Finally, intrinsic ethnic and cultural differences could have an effect on the weight gain profile of Singaporean mothers. Our findings clearly indicate the need for individualized guidelines for our Singaporean Asian population, as also recommended in the 2009 IOM guidelines.

Given the multiethnic composition of the Singaporean population and cultural differences among the three major ethnic groups, we assessed the optimal GWG values and ranges for each of the three ethnic groups in exploratory analyses. The optimal GWG values for each ethnic group were within the optimal GWG range determined using the combined sample, suggesting the overall optimal GWG range is applicable across ethnic groups. Interestingly, the optimal GWG estimates for Malays were relatively higher than the Chinese and Indians even for those in the same BMI category. However, given the relatively small number of Malay and Indian women in our sample, their estimates should be interpreted with caution.

### Limitations
In addition to SGA, LGA and CS deliveries, other adverse perinatal outcomes, such as low Apgar scores and poor fetal growth may be relevant to the establishment of an optimal GWG estimate. We did not consider these outcomes due to their low rates in our sample. Further, inclusion of these outcomes in our analytical approach would result in an unrealistic number of categories for the composite outcome. Given the lack of postnatal maternal and child medical records, we were also not able to examine the effects of GWG on maternal post-partum weight retention or childhood obesity, which are additional outcomes shown by others to be associated with excessive GWG. There were also an insufficient number of obese women to allow subgroup analyses by mild, moderate and severe obesity.

This study, the first to determine optimal GWG in the multiethnic Asian population in Singapore, agrees partially with the IOM guidelines. It concurs with the IOM guidelines in that GWG among Asian women who are heavier prior to pregnancy, especially those who are obese, should be lower than those who are underweight or of normal weight. However, our optimal GWG estimate for underweight and obese women fell outside the IOM recommended range. Further research including a larger number of women, their newborns and other adverse perinatal outcomes is needed to conclusively determine the optimal GWG for Asian populations.

### Acknowledgments
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**Table 5** Optimal GWG corresponding to the lowest sum of risk of adverse outcomes, by ethnic group

<table>
<thead>
<tr>
<th>BMI category</th>
<th>Chinese</th>
<th>Optimal GWG (kg) Malay</th>
<th>Indian</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight (&lt;18.5 kg/m²)</td>
<td>18.9 (13.9 to 24.4)†</td>
<td>21.0 (16.0 to 27.0)</td>
<td>17.6 (12.0 to 24.0)</td>
</tr>
<tr>
<td>Normal (18.5 to &lt;23 kg/m²)</td>
<td>12.4 (6.8 to 17.6)</td>
<td>15.0 (9.0 to 20.0)</td>
<td>11.6 (5.6 to 17.6)</td>
</tr>
<tr>
<td>Overweight (23 to &lt;27.5 kg/m²)</td>
<td>7.1 (1.8 to 12.4)</td>
<td>9.9 (4.0 to 15.3)</td>
<td>7.1 (1.3 to 13.3)</td>
</tr>
<tr>
<td>Obese (≥27.5 kg/m²)</td>
<td>-1.0 (−6.0 to 4.5)</td>
<td>1.2 (−4.0 to 7.0)</td>
<td>-1.0 (−7 to 4.2)</td>
</tr>
</tbody>
</table>

†Numbers in parentheses represent the lower and upper margins of the GWG range for which aggregated risk of composite adverse outcome does not exceed a 5% increase from the lowest aggregated risk. BMI, body mass index; GWG, gestational weight gain.
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