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# **Social inequality in pre-pregnancy BMI and gestational weight gain in the first and second pregnancy among women in Sweden**

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## **Abstract**

**Background:** High pre-pregnancy body mass index (BMI) and inappropriate gestational weight gain (GWG) are associated with adverse short and long-term maternal and neonatal outcomes and may act as modifiable risk factors on the path to overweight/obesity, but their social patterning is not well established. This study investigates the association of education with BMI and GWG across two consecutive pregnancies.

**Methods:** The study includes 163,352 Swedish women, having their first and second singleton birth in 1982-2010. In both pregnancies, we investigated the association of women's education with i) pre-pregnancy weight status and ii) adequacy of GWG. We used multinomial logistic regression, adjusting for child's birth year, mother's age and smoking status.

**Results:** Overall, the odds of starting either pregnancy at an unhealthy BMI were higher among women with a low education compared to more highly-educated women. Lower education also predicted a greater increase in BMI between pregnancies, with this effect greatest among women with excessive GWG in the first pregnancy ( $p < 0.0001$  for interaction). Education was also inversely associated with odds of excessive GWG in both pregnancies among healthy weight status women, but this association was absent or even weakly reversed among overweight and obese women.

**Conclusion:** Lower educated women had the largest BMI increase between pregnancies, and these inequalities were greatest among women with excessive GWG in the first pregnancy. The importance of a healthy pre-pregnancy BMI, appropriate GWG and a healthy postpartum weight should be communicated to all women, which may assist in reducing existing social inequalities in body weight.

**Key Words:** educational status; socioeconomic position; body mass index; gestational weight gain; social inequalities; pregnancy.

## **Highlights**

### *What is already known on this subject?*

- High pre-pregnancy body mass index and excessive gestational weight gain have been associated with adverse short and long-term consequences for mother and child
- In the first pregnancy, low socioeconomic position is associated with high pre-pregnancy body mass index and excessive gestational weight gain (among women of healthy weight status). Low socioeconomic position is also associated with long term obesity

### *What this study adds?*

- Women with a low education had increased risk of starting their first and second pregnancies at an unhealthy weight and had the greatest increase in body mass index between pregnancies. This association was strongest among women who gained weight excessively in their first pregnancy. Among healthy weight women, there was a protective effect of education on excessive gestational weight gain in both pregnancies. Among overweight and obese women, in both pregnancies there was either no significant association between education and gestational weight gain or even a trend in the opposite direction
- Given that gestational weight gain is a modifiable risk factor on the path to overweight/obesity development, ensuring women and practitioners are aware of the most up-to-date guidelines is of priority.

## **Introduction**

Obesity increases the risk of chronic disease, and contributes largely to overall disease burden.<sup>1</sup> While Sweden's prevalence of overweight/obesity is lower than many other high income countries (~40% of women aged 16-84 years),<sup>2</sup> it has increased significantly among all Swedish counties from 1992 to 2010.<sup>3</sup> This is important since pre-pregnancy obesity and excessive gestational weight gain (GWG) are associated with increased risk of several adverse maternal, neonatal and child outcomes.<sup>4,5</sup> In addition, the transition to motherhood involves psychological and behavioural changes that may influence future weight,<sup>6</sup> including through excess GWG and weight retained postpartum.<sup>7,8</sup>

Studies conducted in Australia<sup>9,10</sup> and the UK<sup>11</sup> found greater weight gain over 4 years<sup>10</sup> and 10 years<sup>9,11</sup> among parous women compared to nulliparous, with on average 0.3-4.0kg extra per pregnancy.<sup>11</sup> Likewise in Sweden<sup>12</sup> and the USA,<sup>13</sup> increasing parity is associated with long-term obesity, with some evidence that this particularly reflects the role of the first pregnancy.<sup>14,15</sup>

In the USA<sup>5,16</sup> and Europe<sup>17</sup> excessive GWG is common, particularly among younger women<sup>18</sup> and women with pre-pregnancy overweight/obesity.<sup>11,19</sup> For example, one small Swedish study found excessive GWG among 87% of overweight and 53% of obese women.<sup>19</sup> This matters since high GWG is the strongest predictor of post-partum weight retention<sup>7,8,14,20-22</sup> and of becoming overweight/obese after pregnancy.<sup>21</sup> By contrast, pre-pregnancy BMI is positively associated with weight retention in some<sup>7,15,22</sup> but not all studies.<sup>17,23</sup> These factors likely interact, with greatest weight retention observed among women with both high pre-pregnancy BMI and excessive GWG.<sup>8</sup> The risk of repetition in subsequent pregnancies is plausible,<sup>24</sup> highlighting the importance of accurate GWG advice.

Women with a low socioeconomic position (SEP) are at higher risk of pre-pregnancy overweight/obesity,<sup>1,25</sup> and this social differential seems to have widened over time among obese individuals in Sweden.<sup>26</sup> Lower SEP (measured by education or occupation) is also inversely associated with weight retention<sup>11,20</sup> and long-term BMI in women,<sup>9,27,28</sup> though less is known about the role of SEP for GWG. A Swedish study of primiparous women found that education was protective of excessive GWG only among women of healthy weight status,<sup>25</sup> while a U.S. study found a protective effect of high SEP that was dependent on race and neighbourhood residence.<sup>29</sup>

While GWG is higher in primiparous than multiparous women,<sup>30</sup> we know of no studies investigating SEP differences in BMI change or GWG in the first and second pregnancy. Since GWG is a key modifiable risk factor for development of overweight/obesity, understanding the relationship across consecutive pregnancies may reveal whether the risk is further increased in already disadvantaged groups. This study aimed to investigate the association between education and i) women's change in BMI from before the first pregnancy (BMI1) to before the second (BMI2); and ii) gestational weight gain in the first pregnancy (GWG1) and in the second (GWG2).

## **Methods**

We used data from the Swedish Medical Birth Register and the Education Register, accessed through the Umeå SIMSAM Lab (<http://www.org.umu.se/simsam/english/>). We focused on the 853,148 women with a first and second singleton birth between 1982 and 2010.

Of these women, 522,581 had pre-pregnancy BMI available for both pregnancies and 196,739 (23%) also had complete information on GWG1 and GWG2 (weight data not collected in 1990 and 1991).<sup>31</sup> We excluded 2,029 women with implausible values (Supplementary File 1), 16,774 with missing education data, and 14,584 with missing data on smoking during pregnancy. This left a study population of 163,352 (19% of the total population).

In assessing the potential for selection bias, we found similar characteristics in the women excluded due to missing information (n=689,796) as in our study population (N=163,352). The only significant differences were small: excluded women had a higher mean BMI1 (~0.4kg/m<sup>2</sup> higher) and BMI2 (~0.6kg/m<sup>2</sup> higher) and were slightly more likely to be non-smokers (84% vs. 81% in the first pregnancy). Excluded women also had marginally higher education levels (35% vs. 32% in the first pregnancy).

### **Primary exposure – education**

Woman's education was recorded for each index child's birth year, except for births in 1982-1984, where education was recorded in 1985 since no annual education was available. Education was categorised as low (primary and lower secondary, ≤10 years education), intermediate (upper secondary, ≤13 years education) or high (post-secondary).

### **Outcome variables - BMI and GWG in the first and second pregnancy**

BMI before the first pregnancy (BMI1) and the second pregnancy (BMI2) were calculated based on height and pre-pregnancy weight. Self-reported/measured pre-pregnancy weight was recorded at registration for antenatal care (~8-12 weeks gestation) from 1992 onwards, and was calculated by combining self-reported/measured weight at delivery and GWG for women giving birth before 1992<sup>31</sup> (the extent of self-report vs. measured weights is unknown). Based on pre-pregnancy BMI and World Health Organisation (WHO) definitions,<sup>32</sup> weight status before the first and second pregnancy was categorised as underweight (<18.50 kg/m<sup>2</sup>), healthy weight (18.50-24.99 kg/m<sup>2</sup>), overweight (25.00-29.99 kg/m<sup>2</sup>) or obese (≥30.00 kg/m<sup>2</sup>).

Using the US Institute of Medicine's (IOM) guidelines, we defined adequate GWG as: 12.5-18kg for underweight; 11.5-16kg for healthy weight; 7-11.5kg for overweight; and 5-9kg for obese women.<sup>33</sup> GWG1 and GWG2 were categorised as excessive if above this recommended weight gain, and as inadequate if below. While the IOM guidelines have been criticised in Sweden as being too generous, particularly for overweight/obese women,<sup>34</sup> to date they remain the only official GWG guidelines.

## **Covariates**

For each pregnancy, we obtained data on mother's cigarette smoking as recorded at first antenatal care visit (non-smoker, 1-9 cigarettes/day, 10+ cigarettes/day) and mother's age. The WHO recommends an interval of 18-27 months between a live birth and the next pregnancy, implying an ideal interval around 27-36 months between subsequent births.<sup>35</sup> We categorised birth the birth interval between child 1 and 2 as <27, 27-36, 36.1-68, >68 months).

## **Statistical analyses**

Descriptive statistics explored the association of education and maternal characteristics with the two main outcomes: i) BMI change between pregnancies, stratified by GWG1; and ii) GWG1 and GWG2, stratified by weight status before the pregnancy in question. Multinomial logistic regression investigated social patterning of GWG1 and GWG2 (stratified by weight status). Initially, all were minimally adjusted for the index child's birth year (Model 1), followed by adjustment for mother's age, pre-pregnancy BMI and smoking status (Model 2). Analysis of GWG2 was further adjusted for birth interval in Model 2. We also tested for interactions to see whether the association between education and GWG differed between the two pregnancies.

In supplementary analyses, multinomial logistic regression investigated social patterning of weight status prior to both pregnancies, additionally adjusted for mother's age and smoking status (Model 2). Analysis of weight status prior to the second pregnancy was further adjusted for GWG1 and birth interval (Model 3).

All findings were very similar in sensitivity analyses including full term pregnancies only (N=152,202). All findings with respect to first births were very similar in analyses including all women with a first birth (but not necessarily second, N=440,639). Analyses were performed using SAS 9.3 (SAS Institute Inc., Cary, NC). The study was approved by the regional ethics board in Umeå (Dnr 2010-157-31 Ö)

## Results

Approximately 15% of the women in the sample had a low education (Table 1). The mean age at the birth of first child was 26.3 years, and 29.4 years at the birth of the second child. Slightly more women smoked during the first pregnancy (19%) than the second (16%). Fewer women had a healthy weight status before the second pregnancy (~69%) than the first (~75%).

**Table 1: Description of study population of Swedish women with a first and second singleton birth between 1982-2010 (N=163 352)**

	<b>1<sup>st</sup> pregnancy</b>	<b>2<sup>nd</sup> pregnancy</b>
	<i>Mean (Std dev)</i>	<i>Mean (Std dev)</i>
<b>Height (cm)</b>	166.5 (6.0)	166.5 (6.0)
<b>Weight (kg)</b>	63.0 (10.7)	65.0 (11.8)
<b>Age at birth of index child</b>	26.3 (4.3)	29.4 (4.4)
	<b>n (%)</b>	<b>n (%)</b>
<b>Education<sup>a</sup></b>		
Low	27 976 (17.1)	25 195 (15.4)
Intermediate	83 794 (51.3)	83 697 (51.2)
High	51 582 (31.6)	54 460 (33.3)
<b>Weight status</b>		
Underweight (BMI < 18.5)	9 503 (5.8)	7 834 (4.8)
Healthy weight (BMI 18.5-24.9)	122 242 (74.8)	112 013 (68.6)
Overweight (BMI 25.0–29.9)	24 783 (15.2)	32 395 (19.8)
Obese (BMI ≥ 30.0)	6 824 (4.2)	11 110 (6.8)
<b>Gestational Weight Gain<sup>b</sup></b>		
Inadequate	37 926 (23.2)	41 726 (25.5)
Adequate	64 762 (39.7)	67 969 (41.6)
Excessive	60 664 (37.1)	53 657 (32.9)
<b>Interval since last birth<sup>c</sup></b>		
<27 months	n/a	60 771 (37.2)
27-36 months		40 388 (24.7)
36.1-68 months		50 787 (31.1)
>68 months		11 406 (7.0)
<b>Smoking status</b>		
Non-smoker	131 863 (80.7)	137 155 (83.9)
1-9 cigarettes/day	21 386 (13.1)	17 226 (10.6)
10+ cigarettes /day	10 103 (6.2)	8 971 (5.5)

BMI= body mass index

<sup>a</sup> Education level at the time of the index pregnancy: Low – primary and lower secondary ≤ 10 years,

Intermediate – upper secondary ≤ 13 years, High – post secondary

<sup>b</sup> Gestational weight gain based on the Institute of Medicine's guidelines for BMI specific weight gain in pregnancy

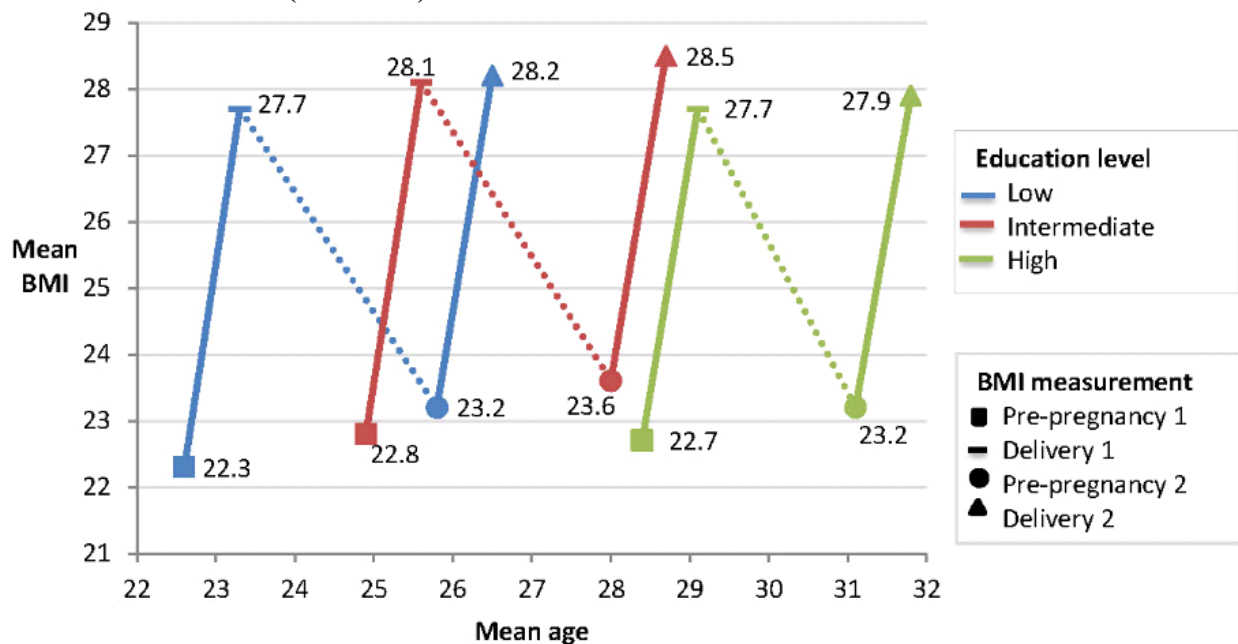
<sup>c</sup> Based on the WHO recommendation of a birth to pregnancy interval of 18-27 months after a live birth (equivalent to a 27-36 month birth interval)



## BMI before the first and second pregnancy

BMI was similar across education groups, despite high-educated women having their first birth at a mean age ~3.5 and ~5.8 years older than intermediate and low-educated women, respectively (Figure 1). Adjusting for age at first birth, low and intermediate-educated women had markedly increased odds of overweight and obesity before the first pregnancy, and also increased odds of underweight status (Supplementary File 2). These differences were only marginally attenuated following adjustment for smoking, indicating that smoking status accounts for only a small part of the association between education and weight status.

**Fig 1** Descriptive figure showing mean body mass index (BMI) measured at 4 time points (before the first pregnancy, at first delivery, before the second pregnancy and at the second delivery), stratified by women's education level (N=163 352).

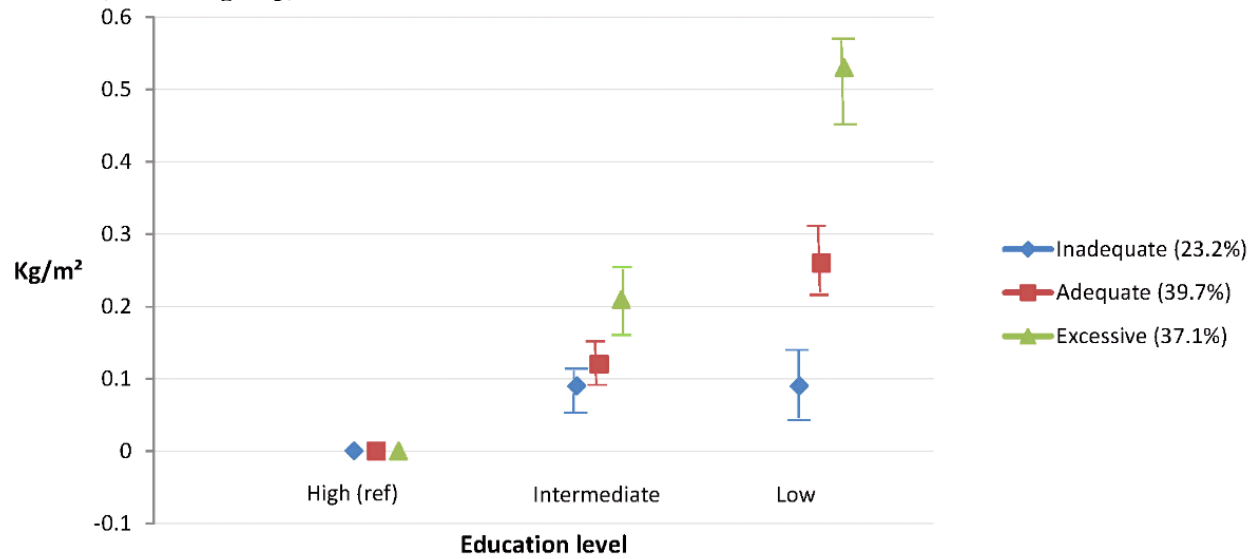


BMI at all 4 time points was significantly associated with education level ( $p < 0.0001$ ). Education level measured near the time of the index pregnancy: Low – primary and lower secondary  $\leq 10$  years, Intermediate – upper secondary  $\leq 13$  years, High – post secondary. Note: The dotted line represents the time period between the first delivery and before the second pregnancy, time for which we do not have weight information

Lower education was also associated with a greater BMI change between pregnancies (a mean absolute increase per year of  $+0.27 \text{ kg/m}^2$  among low-educated,  $+0.21 \text{ kg/m}^2$  among intermediate-educated and  $+0.16 \text{ kg/m}^2$  among high-educated women). This meant that the education gradient in the odds of overweight and obesity had grown even steeper by the start of the second pregnancy ( $p < 0.0001$  for interaction, Supplementary File 2).

Finally, the magnitude of the association between education and BMI change was moderated by GWG1 ( $p < 0.0001$ , Figure 2). Specifically, the relative difference in BMI change between education groups was greater among women who gained weight excessively during their first pregnancy than among women gaining weight adequately or inadequately (Figure 2).

**Fig 2 Mean change in body mass index (BMI) between the first and second pregnancy by education level, stratified by gestational weight gain in the first pregnancy (N=163 352). The figure shows the additional increase in BMI between pregnancies among the lower educated women, compared to high-educated women (reference group).**

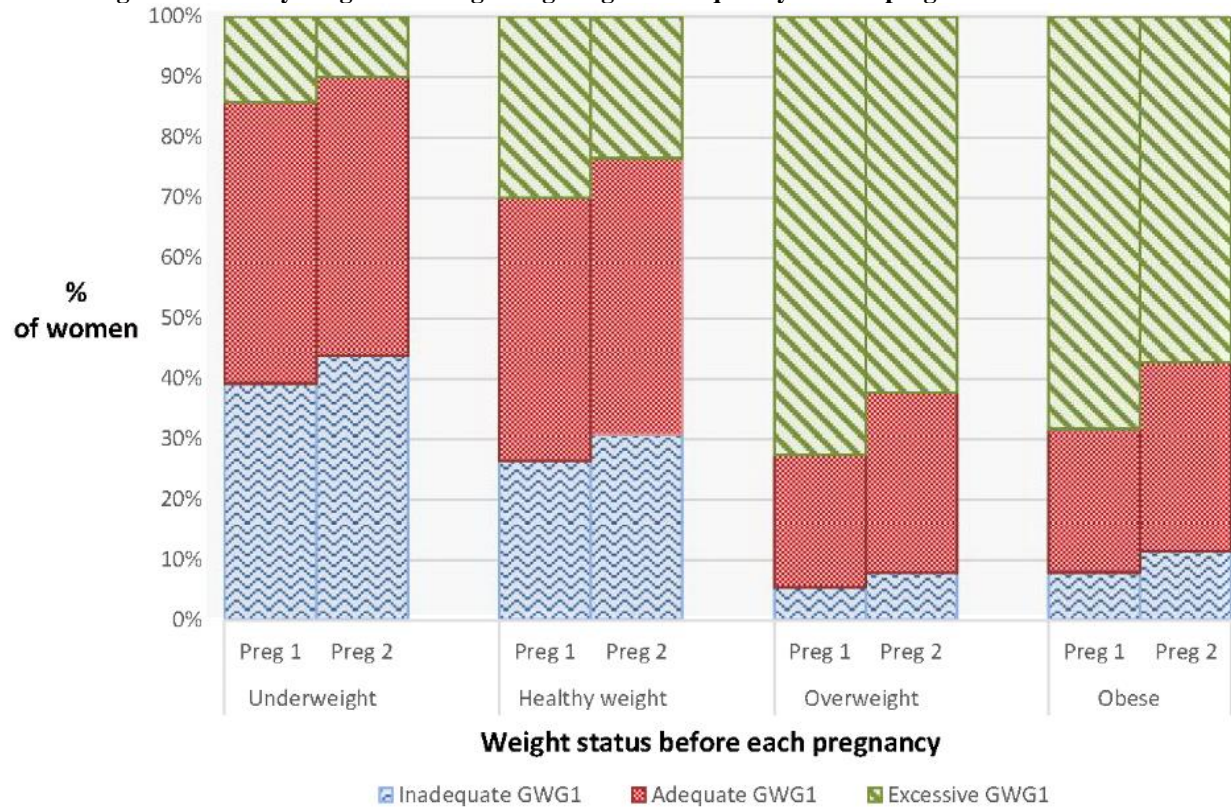


Education level was measured near the time of the first pregnancy: Low – primary and lower secondary  $\leq 10$  years, Intermediate – upper secondary  $\leq 13$  years, High – post secondary. GWG is based on the Institute of Medicine’s guidelines for BMI specific weight gain in pregnancy. Note: Analysis adjusted for birth interval between child 1 and 2, own age and birth year. Significant interaction found between education and gestational weight gain ( $p < 0.0001$ )

### **GWG in the first and second pregnancy**

The proportion of women with adequate GWG1 and GWG2 was slightly higher among underweight than healthy weight women, and markedly higher among healthy weight than overweight or obese women (Table 2 and Figure 3).

**Fig 3 Proportion of women gaining weight inadequately, adequately and excessively in each pregnancy, stratified by pre-pregnancy weight status. The figure shows a large proportion of overweight and obese women gaining weight excessively in both pregnancies, as well as a considerable proportion of underweight and healthy weight women gaining weight inadequately in both pregnancies.**



Preg1=pregnancy 1, Preg2= pregnancy 2. GWG= Gestational weight gain is based on the Institute of Medicine’s guidelines for BMI specific weight gain in pregnancy

**Table 2: Bivariate association between education and gestational weight gain in first (GWG1) and second pregnancy (GWG2), among Swedish women with a first and second singleton birth between 1982-2010. Results stratified by weight status before the index pregnancy (N=163 352)**

Education*stratified by weight status	Gestational weight gain <sup>a</sup>									
	1 <sup>st</sup> pregnancy: GWG1					2 <sup>nd</sup> pregnancy: GWG2				
	N	Inadequate (%)	Adequate (%)	Excessive (%)	p-value	N	Inadequate (%)	Adequate (%)	Excessive (%)	p-value
<b>Underweight</b>					<0.0001					<0.0001
High	2 102	44.7	46.1	9.2		1 967	47.4	44.6	8.0	
Intermediate	4 799	37.7	47.9	14.4		3 938	42.7	47.4	9.9	
Low	2 602	37.7	44.6	17.7		1 929	43.3	44.6	12.1	
<b>Healthy weight<sup>b</sup></b>					<0.0001					<0.0001
High	40 273	28.3	46.5	25.2		39 651	31.8	47.4	20.8	
Intermediate	61 528	25.4	43.0	31.6		55 802	30.1	45.5	24.4	
Low	20 441	25.8	39.5	34.7		16 560	30.8	42.6	26.6	
<b>Overweight</b>					<0.0001					<0.0001
High	7 430	5.1	22.5	72.4		10 058	6.4	30.0	63.6	
Intermediate	13 457	5.1	22.1	72.8		17 424	7.8	30.0	62.2	
Low	3 896	7.2	20.9	71.9		4 913	10.5	28.7	60.8	
<b>Obese</b>					0.17					0.0002
High	1 777	7.5	24.0	68.5		2 784	9.6	30.0	60.4	
Intermediate	4 010	7.7	23.4	68.9		6 533	11.9	31.5	56.6	
Low	1 037	9.7	24.1	66.2		1 793	12.2	33.3	54.5	

GWG= Gestational weight gain. \*Education level near the time of index pregnancy: Low – primary and lower secondary ≤ 10 years, Intermediate – upper secondary ≤ 13 years, High – post secondary

<sup>a</sup>BMI-specific gestational weight gain, classified by IOM criteria and NRC. <sup>b</sup>Healthy weight refers to the WHO BMI weight status category of ‘normal weight’, i.e. with BMI of 18.50-24.99 kg/m<sup>2</sup>.

In the second pregnancy, a smaller proportion of women gained weight excessively, while a larger proportion of women gained weight inadequately or adequately (Table 2). Inadequate weight gain was particularly striking among underweight and healthy weight women; this was observed in ~40% of underweight and ~30% of healthy weight women in both pregnancies. Compared to WHO recommended birth intervals,<sup>35</sup> a longer interval was associated with increased odds of excessive GWG2 among healthy and overweight women, while a shorter interval was associated with decreased odds of excessive GWG2 (Table 3). A shorter interval was also associated with increased odds of inadequate GWG2 among healthy and underweight women (Table 3).

### **Social patterning of GWG**

Among healthy weight women there was an association between increasing education and a decreased proportion of excessive GWG1 and GWG2 (Table 2). These associations were attenuated but remained highly significant after adjusting for maternal BMI (continuous – separate results not shown); estimates further marginally attenuated after adjusting for maternal smoking (Table 3, Model 2) and birth interval (Table 3, Model 3). Overall, these associations were stronger in the first pregnancy ( $p < 0.0001$  for interaction, Table 3).

**Table 3: Association between education and gestational weight gain in the first and second pregnancy, among Swedish women with a first and second singleton birth between 1982-2010. Odds ratios and 95% CI from multinomial regression analysis (n=163 352)**

Education <sup>a</sup> stratified by weight status	IOM gestational weight gain <sup>b</sup> (adequate GWG as reference)											
	Inadequate						Excessive					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
<b><u>1<sup>st</sup> Pregnancy</u></b>												
<b>Underweight</b>												
High (Ref)	1.00		1.00				1.00		1.00			
Intermediate	<b>0.85</b>	<b>0.76, 0.96</b>	<b>0.86</b>	<b>0.77, 0.97</b>			<b>1.35</b>	<b>1.12, 1.63</b>	<b>1.32</b>	<b>1.09, 1.60</b>		
Low	0.94	0.82, 1.09	0.97	0.84, 1.13			<b>1.68</b>	<b>1.35, 2.08</b>	<b>1.59</b>	<b>1.27, 1.98</b>		
<b>Healthy weight<sup>c</sup></b>												
High(Ref)	1.00		1.00				1.00		1.00			
Intermediate	<b>0.97</b>	<b>0.94, 1.00</b>	<b>0.97</b>	<b>0.93, 0.99</b>			<b>1.26</b>	<b>1.22, 1.30</b>	<b>1.22</b>	<b>1.18, 1.26</b>		
Low	<b>1.06</b>	<b>1.02, 1.12</b>	1.05	0.99, 1.10			<b>1.44</b>	<b>1.38, 1.51</b>	<b>1.36</b>	<b>1.30, 1.43</b>		
<b>Overweight</b>												
High (Ref)	1.00		1.00				1.00		1.00			
Intermediate	0.97	0.84, 1.13	0.95	0.81, 1.10			0.96	0.89, 1.03	0.98	0.91, 1.05		
Low	<b>1.42</b>	<b>1.17, 1.73</b>	<b>1.36</b>	<b>1.11, 1.66</b>			0.97	0.87, 1.08	1.00	0.90, 1.05		
<b>Obese</b>												
High (Ref)	1.00		1.00				1.00		1.00			
Intermediate	0.95	0.74, 1.21	0.89	0.69, 1.14			0.99	0.86, 1.14	1.03	0.89, 1.19		
Low	1.03	0.74, 1.44	0.94	0.67, 1.33			0.92	0.75, 1.12	0.97	0.79, 1.19		
<b><u>2<sup>nd</sup> Pregnancy</u></b>												
<b>Underweight</b>												
High (Ref)	1.00		1.00		1.00		1.00		1.00		1.00	
Intermediate	<b>0.89</b>	<b>0.79, 1.00</b>	0.89	0.79, 1.01	0.91	0.81, 1.03	1.08	0.87, 1.34	1.04	0.84, 1.30	1.01	0.81, 1.26
Low	0.97	0.83, 1.12	0.96	0.82, 1.12	0.99	0.85, 1.16	<b>1.31</b>	<b>1.02, 1.68</b>	1.21	0.93, 1.58	1.17	0.89, 1.52
<i>Child 1-2interval<sup>d</sup> (months)</i>												
<27					<b>1.30</b>	<b>1.16, 1.46</b>					0.87	0.72, 1.06
27-36 (Ref)					1.00						1.00	
36.1– 68					0.97	0.85, 1.10					1.12	0.92, 1.38
>68					1.01	0.77, 1.32					1.13	0.73, 1.74
<b>Healthy weight<sup>c</sup></b>												
High (Ref)	1.00		1.00		1.00		1.00		1.00		1.00	
Intermediate	<b>1.04</b>	<b>1.01, 1.08</b>	1.02	0.98, 1.05	1.03	1.00, 1.06	<b>1.17</b>	<b>1.13, 1.21</b>	<b>1.14</b>	<b>1.10, 1.18</b>	<b>1.10</b>	<b>1.06, 1.14</b>

Low	<b>1.22</b>	<b>1.16, 1.28</b>	<b>1.13</b>	<b>1.08, 1.19</b>	<b>1.15</b>	<b>1.09, 1.21</b>	<b>1.32</b>	<b>1.26, 1.39</b>	<b>1.29</b>	<b>1.22, 1.35</b>	<b>1.22</b>	<b>1.16, 1.28</b>
<i>Child 1-2interval<sup>d</sup> (months)</i>												
<27					<b>1.20</b>	<b>1.16, 1.25</b>					<b>0.87</b>	<b>0.84, 0.91</b>
27-36 (Ref)					1.00						1.00	
36.1–68					0.98	0.94, 1.02					<b>1.16</b>	<b>1.12, 1.21</b>
>68					1.06	1.00, 1.12					<b>1.31</b>	<b>1.23, 1.40</b>
<b>Overweight</b>												
High (Ref)	1.00		1.00		1.00		1.00		1.00		1.00	
Intermediate	<b>1.23</b>	<b>1.10, 1.37</b>	<b>1.15</b>	<b>1.03, 1.29</b>	<b>1.15</b>	<b>1.03, 1.29</b>	<b>0.93</b>	<b>0.88, 0.98</b>	0.95	0.89, 1.01	<b>0.93</b>	<b>0.88, 0.99</b>
Low	<b>1.75</b>	<b>1.51, 2.02</b>	<b>1.51</b>	<b>1.30, 1.76</b>	<b>1.51</b>	<b>1.30, 1.76</b>	<b>0.87</b>	<b>0.79, 0.94</b>	0.92	0.84, 1.00	<b>0.90</b>	<b>0.82, 0.98</b>
<i>Child 1-2interval<sup>d</sup> (months)</i>												
<27					1.09	0.97, 1.22					<b>0.85</b>	<b>0.79, 0.90</b>
27-36 (Ref)					1.00						1.00	
36.1–68					0.92	0.81, 1.04					1.03	0.96, 1.10
>68					1.11	0.93, 1.32					<b>1.13</b>	<b>1.02, 1.25</b>
<b>Obese</b>												
High (Ref)	1.00		1.00		1.00		1.00		1.00		1.00	
Intermediate	<b>1.22</b>	<b>1.04, 1.44</b>	1.11	0.93, 1.31	1.10	0.92, 1.30	0.96	0.87, 1.07	0.96	0.87, 1.07	0.95	0.86, 1.06
Low	<b>1.30</b>	<b>1.05, 1.61</b>	1.10	0.87, 1.38	1.08	0.86, 1.37	0.94	0.82, 1.08	0.95	0.82, 1.10	0.93	0.81, 1.08
<i>Child 1-2interval<sup>d</sup> (months)</i>												
<27					1.01	0.84, 1.20					0.99	0.88, 1.10
27-36 (Ref)					1.00						1.00	
36.1–68					0.94	0.79, 1.13					0.93	0.83, 1.04
>68					1.12	0.88, 1.42					1.13	0.96, 1.32

CI=confidence intervals, GWG=gestational weight gain, IOM= Institute of Medicine, OR=odds ratio, Ref= reference group

Model 1: adjusted for birth year of index child and woman's age, Model 2: Model 1 + BMI and smoking at index pregnancy, Model 3: Model 2 + birth interval between child 1 and 2.

Model 1 - overall interaction between education and parity was significant ( $p < 0.0001$ ). Interaction stratified by pre-pregnancy BMI: underweight  $p = 0.24$ , healthy weight  $p < 0.0001$ , overweight  $p = 0.04$ , obese  $p = 0.19$ .

<sup>a</sup> Education level at the time of the index pregnancy: Low – primary and lower secondary  $\leq 10$  years, Intermediate – upper secondary  $\leq 13$  years, High – post secondary

<sup>b</sup> BMI-specific gestational weight gain, classified by IOM criteria and NRC. Adequate gestational weight gain as the reference.

<sup>c</sup> Healthy weight refers to the WHO BMI weight status category of 'normal weight', i.e. with BMI of 18.50-24.99 kg/m<sup>2</sup>.

<sup>d</sup> Based on the WHO recommendation of a birth to pregnancy interval of 18-27 months after a live birth (equivalent to a 27-36 month birth interval)

Results in bold indicate statistical significance at the 0.05 level.

Higher education also predicted decreased odds of excessive GWG1 and GWG2 among underweight women (Table 2, Table 3). There was again a trend towards a stronger effect in the first pregnancy, but this was not significant ( $p=0.24$ ).

By contrast, in regression analyses among overweight and obese women, the education gradient in excessive GWG showed a trend in the opposite direction (though non-significant among obese women, Table 3); that is, there was a trend towards lower odds of excessive GWG among low-educated overweight or obese women. Low-educated overweight women also had increased odds of inadequate GWG1 and GWG2, compared to high-educated women (Table 3, Model 2). Among overweight women, the effect of education on GWG was stronger in the first pregnancy ( $p=0.04$  for interaction).

## **Discussion**

Among women in Sweden, we found that those with a lower education were more likely to start their first and second pregnancy at an unhealthy weight; these women also experienced a greater increase in BMI between pregnancies. The education gradient for change in BMI was particularly large among women who had experienced the risk factor of gaining weight excessively in the first pregnancy. We also found that, among women with a healthy pre-pregnancy weight status, those with a lower education were in both pregnancies more likely to experience excessive GWG. However, this educational gradient in excessive GWG was generally non-significant among women who started their pregnancy overweight or obese, and moreover the trend was consistently in the opposite direction. Thus, higher education appeared not to be protective against excessive GWG among overweight/obese women.

The protective association between higher education and pre-pregnancy weight status supports previous findings focused on first pregnancies among Swedish women.<sup>25</sup> In our study, BMI1 and BMI2 were very similar between education groups, despite the fact that the average age at first birth was considerably older among high-educated women (~3.5 and ~5.8 years older). This is important from a public health perspective, underlining that increasing BMI is not solely determined by age and remains a modifiable maternal and neonatal risk factor.

The inverse association found for education and BMI change between pregnancies is similar to other studies of education and postpartum weight retention<sup>11, 20</sup> and long-term BMI.<sup>9, 27, 28</sup> This educational gradient in BMI change amplified the pre-existing gradient in overweight/obesity, generating an educational gradient in overweight/obesity that was even stronger in the second pregnancy than the first (even after adjusting for birth interval). This finding highlights chains of interacting risks that may magnify existing social inequalities over time, as does our finding that the educational gradient in BMI change was particularly steep among women with excessive GWG1.

Consistent with evidence of excessive GWG accelerating overweight/obesity development in women,<sup>7, 8</sup> we found increased odds of overweight/obesity before the second pregnancy among women with excessive GWG in the first pregnancy. As weight



gain is largely a modifiable risk factor, accurate information and implementation of existing guidelines may considerably improve GWG outcomes. Although accurate advice in itself may not be enough to assist women to gain weight adequately,<sup>36</sup> being advised to gain too much weight is associated with excessive GWG.<sup>37</sup> This may be due to practitioners being unaware of current guidelines<sup>38</sup> or advising women incorrectly, particularly overweight/obese women.<sup>39</sup> Ensuring wide access to up-to-date guidelines may provide women (especially low educated women) the opportunity to set a healthy, weight-status-appropriate GWG target. Similar to a U.S. study,<sup>14</sup> we found a higher proportion of women gaining weight adequately in the second pregnancy, compared to the first. However it remains of clinical importance that ~40% of underweight and ~30% of healthy weight women gained inadequately in both pregnancies.

Among healthy and underweight women, we found a protective association between education and odds of excessive GWG in the first pregnancy. This accords with results among healthy weight women in a smaller Swedish study of first births.<sup>25</sup> Possible explanations for this association include improved diet/physical activity patterns, greater compliance to medical instruction, better access to information and earlier weight trajectories, as well as personality characteristics and reinforced social norms among higher-educated women. The potential mediating/moderating role of behavioural factors such as smoking, diet and physical activity on weight gain in pregnancy should be addressed in future studies. Also of interest would be investigation of whether/how the associations with women's current educational level may reflect differences in women's growth trajectories and health or personality characteristics emerging earlier during their life course.

By contrast, the protective effect of education on excessive GWG was absent among overweight and obese women. Indeed, if anything, the trend was in the opposite direction, although it only reached significance for overweight women in the second pregnancy. The reason for this absence (or even reversal) of the education gradient is unclear; speculatively, it may be that overweight/obese women are a more closely monitored group, particularly if they experience excessive GWG in the first pregnancy. In any case, these results suggest that maintaining a healthy weight during pregnancy may be a challenge for women from all educational groups, particularly if the woman's pre-pregnancy BMI is high.

Finally, a shorter than WHO recommended birth interval<sup>35</sup> was associated with increased odds of inadequate GWG2 among healthy and underweight women. Increased odds of excessive GWG2 were found among healthy and overweight women with a longer than recommended birth interval. This suggests that women with a shorter and longer than recommended birth interval may be potentially at-risk and require additional monitoring and advice.

### **Strengths and limitations**

While using high-quality register data is a strength, potential limitations include a large proportion of women excluded due to missing data, partly due to administrative reasons

(data not collected during two calendar years). Reassuringly, the characteristics of excluded women were very similar to women with complete data. Nevertheless, the potential for some selection bias remains. For example, a relatively high proportion of women lacked data on GWG, and it is possible that women appearing to gain weight appropriately would be less closely monitored and as such be missing GWG data. Additionally, we cannot exclude possible measurement error due to using self-reported data on height and weight, although both are found reasonable for epidemiological studies.<sup>40</sup>

While a steady increase in prevalence of pre-pregnancy overweight/obesity has been observed over time in Sweden, there was an unexpectedly large increase from 1989 to 1992, which we suspect is a possible artefact of changes in BMI measurement before and after 1992. While this is unlikely to vary by education level and significantly influence our results, all models were minimally adjusted for birth year of the child to account for this. Finally, it is arguably a limitation that we applied the 2009 IOM guidelines to data collected in Sweden and between 1982 and 2010, i.e., prior to when the guidelines were written. We made this decision based on i) an absence of Swedish guidelines and ii) a desire to define weight gain in relation to what is healthy for mother and child, even if this does not necessarily match the advice women received.

## **Conclusion**

Our results show a protective effect of education for starting pregnancy at a healthy weight; avoiding a high BMI increase between pregnancies; and (among healthy-weight women) avoiding excessive GWG. While assisting women to start their first pregnancy at a healthy weight should remain a priority, targeting GWG as a key modifiable risk factor on the path to overweight/obesity should also be considered; namely, focusing on achieving GWG within the IOM guidelines, as well as returning to a healthy postpartum weight within a reasonable time frame. Our research identifies women who may be at particular increased risk of later overweight/obesity. This includes low educated women who gain weight excessively in the first pregnancy, and are therefore particularly likely to experience a large BMI increase between pregnancies. It also includes overweight/obese women of any educational group, who are particularly likely to experience excessive GWG during pregnancy.

Pregnancy is a time when women are both concerned about their child's health and heavily engaged with health professionals; as such, it provides a unique opportunity for lifestyle modifications which may prevent overweight/obesity and improve long-term health outcomes for mother and child. Our results could inform the design of both universal and targeted interventions, including supporting women to start their pregnancy at a healthy BMI, to gain weight appropriately and to return to a healthy pre-pregnancy BMI in a reasonable time.

## **Conflict of interest**

None

## **Funding and acknowledgements**

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**Supplementary file 1; Exclusion of women with implausible values for height, pre-pregnancy weight or gestational weight gain**

We excluded women with a height  $\leq 150$ cm or  $\geq 200$ cm, pre-pregnancy weight of  $\leq 34$ kg or  $\geq 200$ kg; GWG  $\geq 41$ kg. Additionally we excluded implausible combinations of BMI and height: BMI  $< 16$  and height  $\geq 180$ cm; BMI  $> 35$  and height  $< 130$ ; BMI  $< 12$ . We further sequentially excluded 2,029 women with implausible values; 3 women with an inter-birth interval  $< 9$  months; 222 women with weight change per year between pregnancies greater than 15kg; and 1,804 women with GWG in the first or second pregnancy of less than 1kg or greater than 35kg, consistent with an earlier analysis of Swedish data[1] and a population study which suggested that extremes in GWG may be related to uncommon pathologies[2].

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**Supplementary File 2: Association between education and weight status before the first and second pregnancy, among Swedish women with a first and second singleton birth between 1982-2010. Odds ratios and 95% C.I. from multinomial regression analysis (N=163,352)**

Education <sup>a</sup>	Pre-pregnancy weight status							
	Underweight		Healthy weight <sup>b</sup>	Overweight		Obese		
	OR	95% CI	Ref	OR	95% CI	OR	95% CI	
<b><u>1<sup>st</sup> Pregnancy</u></b>								
Model 1 (adjusted for birth year of child and woman's age)								
High (Ref)		1.00	1.00		1.00		1.00	
Intermediate	<b>1.10</b>	<b>1.04, 1.17</b>	1.00	<b>1.46</b>	<b>1.41, 1.51</b>	<b>2.22</b>	<b>2.08, 2.36</b>	
Low	<b>1.46</b>	<b>1.36, 1.56</b>	1.00	<b>1.50</b>	<b>1.43, 1.58</b>	<b>2.41</b>	<b>2.20, 2.63</b>	
Model 2 (Model 1 + smoking)								
High (Ref)		1.00	1.00		1.00		1.00	
Intermediate	<b>1.07</b>	<b>1.00, 1.14</b>	1.00	<b>1.44</b>	<b>1.39, 1.49</b>	<b>2.17</b>	<b>2.04, 2.31</b>	
Low	<b>1.35</b>	<b>1.26, 1.45</b>	1.00	<b>1.46</b>	<b>1.39, 1.53</b>	<b>2.22</b>	<b>2.03, 2.43</b>	
<b><u>2<sup>nd</sup> Pregnancy</u></b>								
Model 1 (adjusted for birth year of child and woman's age)								
High (Ref)		1.00	1.00		1.00		1.00	
Intermediate	1.04	0.98, 1.11	1.00	<b>1.47</b>	<b>1.43, 1.52</b>	<b>2.30</b>	<b>2.19, 2.42</b>	
Low	<b>1.36</b>	<b>1.26, 1.46</b>	1.00	<b>1.66</b>	<b>1.59, 1.73</b>	<b>2.89</b>	<b>2.70, 3.09</b>	
Model 2 (Model 1 + smoking)								
High (Ref)		1.00	1.00		1.00		1.00	
Intermediate	1.00	0.94, 1.06	1.00	<b>1.46</b>	<b>1.42, 1.51</b>	<b>2.26</b>	<b>2.15, 2.37</b>	
Low	<b>1.20</b>	<b>1.11, 1.30</b>	1.00	<b>1.62</b>	<b>1.55, 1.69</b>	<b>2.70</b>	<b>2.52, 2.90</b>	
Model 3 (Model 2 +GWG1 and child 1-2 interval)								
High (Ref)		1.00	1.00		1.00		1.00	
Intermediate	1.06	0.99, 1.12	1.00	<b>1.38</b>	<b>1.34, 1.43</b>	<b>2.07</b>	<b>1.97, 2.18</b>	
Low	<b>1.28</b>	<b>1.18, 1.38</b>	1.00	<b>1.53</b>	<b>1.46, 1.60</b>	<b>2.50</b>	<b>2.32, 2.69</b>	
1 <sup>st</sup> pregnancy GWG <sup>c</sup> (GWG1)								
Inadequate	<b>2.03</b>	<b>1.93, 2.13</b>	1.00	<b>0.54</b>	<b>0.51, 0.56</b>	<b>0.40</b>	<b>0.37, 0.44</b>	
Adequate		1.00	1.00		1.00		1.00	
(Ref)								
Excessive	<b>0.34</b>	<b>0.31, 0.37</b>	1.00	<b>3.43</b>	<b>3.33, 3.53</b>	<b>5.57</b>	<b>5.30, 5.85</b>	
Interval <sup>d</sup> between child 1 and 2 (months)								
<27	1.03	0.97, 1.10	Ref	<b>1.10</b>	<b>1.06, 1.13</b>	<b>1.08</b>	<b>1.02, 1.14</b>	
27 – 36 (Ref)		1.00	Ref		1.00		1.00	
36.1 - 68	<b>0.92</b>	<b>0.86, 0.98</b>	Ref	<b>1.11</b>	<b>1.08, 1.16</b>	<b>1.11</b>	<b>1.05, 1.17</b>	
>68	<b>0.77</b>	<b>0.68, 0.88</b>	Ref	<b>1.22</b>	<b>1.15, 1.29</b>	<b>1.43</b>	<b>1.32, 1.55</b>	

CI=confidence intervals, OR=odds ratio, Ref= reference group, GWG=gestational weight gain

Model 1 interaction between education and parity was significant ( $P < 0.0001$ )

<sup>a</sup> Education level at the time of the index pregnancy: Low – primary and lower secondary  $\leq 10$  years, Intermediate – upper secondary  $\leq 13$  years, High – post secondary

<sup>b</sup> Healthy weight refers to the WHO BMI weight status category of 'normal weight', i.e. with BMI of 18.50-24.99 kg/m<sup>2</sup>.

<sup>c</sup> GWG based on the Institute of Medicine's guidelines for BMI specific weight gain in pregnancy

<sup>d</sup> Based on the WHO recommendation of a birth to pregnancy interval of 18-27 months after a live birth (equivalent to a 27-36 month birth interval)