Interpregnancy weight gain and childhood obesity: analysis of a UK population-based cohort

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BACKGROUND: Maternal obesity increases the risk of adverse long-term health outcomes in mother and child including childhood obesity. We aimed to investigate the association between interpregnancy weight gain between first and second pregnancies and risk of overweight and obesity in the second child.

METHODS: We analysed the healthcare records of 4789 women in Hampshire, UK with their first two singleton live births within a population-based anonymised linked cohort of routine antenatal records (August 2004 and August 2014) with birth/early life data for their children. Measured maternal weight and reported height were recorded at the first antenatal appointment of each pregnancy. Measured child height and weight at 4–5 years were converted to age- and sex-adjusted body mass index (BMI z-score). Log-binomial regression was used to examine the association between maternal interpregnancy weight gain and risk of childhood overweight and obesity in the second child. This was analysed first in the whole sample and then stratified by baseline maternal BMI category.

RESULTS: The prevalence of overweight/obesity in the second child was 19.1% in women who remained weight stable, compared with 28.3% in women with ≥3 kg/m² weight gain. Interpregnancy gain of ≥3 kg/m² was associated with increased risk of childhood overweight/obesity (adjusted relative risk (95% CI) 1.17 (1.02–1.34)), with attenuation on adjusting for birthweight of the second child (1.08 (0.94–1.24)). In women within the normal weight range at first pregnancy, the risks of childhood obesity (≥95th centile) were increased with gains of 1–3 kg/m² (1.74 (1.07–2.83)) and ≥3 kg/m² (1.87 (1.18–3.01)).

CONCLUSION: Children of mothers within the normal weight range in their first pregnancy who started their second pregnancy with a considerably higher weight were more likely to have obesity at 4–5 years. Supporting return to pre-pregnancy weight and limiting weight gain between pregnancies may achieve better long-term maternal and offspring outcomes.
(interval between the birth of a child to the conception of the next child) of ≥36 months is associated with greater risk of starting a subsequent pregnancy at a higher weight [13]. Previous research has found an increased risk of gestational diabetes (GDM), caesarean section [14–16] and pre-eclampsia [15, 16] with interpregnancy weight gain particularly in women with healthy first pregnancy BMI (<25 kg/m²). Interpregnancy weight gain is associated with an increased risk of large-for-gestational age (LGA) birth [10, 11, 17], which, in turn, is associated with both childhood [18, 19] and adult obesity [20–22]. The mechanisms are unclear but the increase in adiposity on weight retention or gain postpartum may be a contributing factor to these associations.

Interpreting the findings from studies on maternal weight change is complicated by the fact that weight gain (e.g. amongst underweight) or loss (e.g. amongst overweight) may differ between individuals and across contexts. To address this, our large population-based study primarily focussed on non-underweight women who maintained or gained weight between their first two pregnancies. The aim was to investigate the association between maternal weight gain between the first and second singleton live birth pregnancies and the risk of overweight and obesity in the second child. As the effect of weight gain/retention may differ by maternal BMI at the start of the pregnancy, we stratified the analyses by maternal BMI. To investigate potential mechanisms, we aimed to examine whether birthweight and postnatal factors such as breastfeeding accounted for the observed relationships.

METHODS
SLOPE (Studying Lifecourse Obesity PrEdictors) is a population-based anonymised linked cohort of prospectively collected routine maternal antenatal and birth records and child health records for all births registered at University Hospital Southampton (UHS), in the South of England, UK between January 2003 and April 2018. UHS is the regional centre for maternity care to residents in the city of Southampton and the surrounding areas of Hampshire. Child healthcare for the same area is provided by two community National Health Service (NHS) trusts; Solent and Southern Health. Thus, the antenatal and birth records (n = 83,481) were then linked to child health data from these two community NHS trusts (n = 74,770, 90% linked).

Records of women with their first two consecutive singleton live birth pregnancies that were successfully linked to child health data for the second child were included. Any woman who had a booking appointment at or after 24 weeks of pregnancy was excluded (Fig. 1). Only pregnancies with feasible gestational age (22–43 weeks), maternal weight and maternal height measurements were eligible for inclusion in this analysis (n = 6357). Women who conceived through infertility treatment in either pregnancies (n = 338), those who were underweight (BMI < 18.5 kg/m²) at first (n = 223) or second pregnancy (n = 62), and those who lost weight (≥1 kg/m²) between pregnancies (n = 945) were excluded from this analysis leaving data from 4789 women for analysis (75% of eligible sample). These exclusions were made to ensure a straightforward comparison between women who maintained and gained weight between pregnancies, and to reduce the potential for residual confounding due to unmeasured changes in health status which may differ between women who lost weight between pregnancies and others.

Exposure assessment
Maternal weight in kilograms was routinely measured by a midwife at the first antenatal (booking) appointment of each pregnancy [23], which is recommended to take place ideally by 10 weeks gestation in the UK, according to the National Institute for Health and Care Excellence Guidelines [24]. Height was self-reported. BMI was calculated as weight/(height²).

BMI at the start of the first pregnancy (baseline BMI) was categorised as normal weight (18.5–24.9 kg/m²), overweight (25.0–29.9 kg/m²) and obesity (≥30 kg/m²). Change in BMI was calculated as the difference in BMI measured at the booking appointments of the first two consecutive live birth pregnancies for each woman. After excluding women who lost weight between their pregnancies (≥1 kg/m²), this change was categorised as weight stable (–1 to 1 kg/m²), moderate weight gain (1–3 kg/m²) (MWG) and substantial weight gain (≥3 kg/m²) (SWG).

Outcome assessment
As part of the National Child Measurement Programme (NCMP), children in all state-maintained schools in England are measured by school nurses at Year R (4–5 years) and Year 6 (10–11 years) [25]. Only the measurement at 4–5 years was used in this analysis and children who did not have a weight and height measurement at 4–5 years were excluded (n = 9474). BMI was then calculated as weight/height² and converted to age- and sex-adjusted BMI z-scores according to the UK 1990 growth reference charts [26]. The 85th percentile (z-score of +1.04) was used to specify the outcome of overweight and obesity and the 95th percentile (z-score of +1.65) was used to specify the outcome of obesity [27, 28].
Covariates
Maternal age (in years) was calculated from date of birth before extraction of the dataset to maintain anonymity. Highest maternal educational qualification was self-reported and categorised as secondary (GCSE) and under, college (A levels) and university degree or above. Self-reported ethnicity was recorded under 16 categories and condensed to White, Mixed, Asian, Black/African/Caribbean and Other. Categories of not asked and not stated were coded as missing. Smoking at booking was self-reported as current smoking or non-smoking. Non-smokers were further asked if they had ever smoked or had previously smoked and quit. This was categorised as stopped >12 months before conception, stopped <12 months before conception or stopped when pregnancy confirmed. Employment status was self-reported and categorised as employed, unemployed, in education, and not specified. In this population, an oral glucose tolerance test was used for screening for GDM in women with one or more risk factors (BMI > 30 kg/m²); GDM in previous pregnancy; previous baby weighing >4.5 kg; diabetes in parents or siblings and of Asian, African-Caribbean or Middle Eastern ethnicity [29]. GDM diagnosis was then reported in the database. Interpregnancy interval was defined as the interval between the first live birth and conception of the second pregnancy. The difference in days between two consecutive live births was calculated and gestational age of the latter birth subtracted from this to derive the interpregnancy interval.

Birthweight (grams) was measured by healthcare professionals at birth as part of routine care. Gestational age was based on a dating ultrasound scan which routinely takes place between 10 and 13 weeks gestation [24]. Child sex was recorded at birth. Breastfeeding status was reported at hospital discharge and during early life. The recording during early life was done differently by the two community NHS Trusts. One used NHS Read codes and thus was recorded at 10 days, 2 weeks, 6 weeks, 4 months and 9 months as breastfed, bottle-fed or breast and bottle fed; breastfeeding could be recorded at any or all of the time-points specified by the Read codes. The other Trust recorded breastfeeding at 56 days (8 weeks) as yes or no so there was no information on whether this was exclusive or partial breastfeeding. There was a small number (n = 10) of responses for breastfeeding for 4 months and 9 months at both pregnancies and no records for 8 weeks (for breastfeeding at first pregnancy only). Using all the information available, a breastfeeding variable was derived with categories of no breastfeeding, minimum 10 days and minimum 6 weeks. Minimum duration was chosen as there was no information how long breastfeeding continued beyond the point of the last record.

Missing data
Of the women included, 83.9% of records had missing values for breastfeeding status at first pregnancy, 61.7% for breastfeeding status at second pregnancy, 3.8% for ethnicity and 0.3% on employment status. We imputed 85 datasets using multiple imputation via chained equations. The imputation models included the outcome and variables of analytical interest without missing values to impute the missing values for ethnicity, employment status and breastfeeding status in first and second pregnancy.

Statistical analysis
Unadjusted comparisons were carried out using ANOVA for continuous variables and chi-square test for categorical variables. Unadjusted comparisons were carried out using ANOVA for continuous variables and chi-square test for categorical variables. Covariates comprised maternal age at first pregnancy, ethnicity, highest educational qualification, employment status at first pregnancy, smoking status at first and second pregnancy, first and second pregnancy gestational age at booking, first pregnancy BMI as measured at booking, GDM in first pregnancy, interpregnancy interval and breastfeeding status for first pregnancy (Model 1). To estimate the controlled direct effect of interpregnancy BMI gain, potential mediators were additionally adjusted for including GDM in second pregnancy, birthweight, gestational age at birth and breastfeeding status for second pregnancy (Model 2).

Although child sex was included as an adjustment variable in the DAG, this was not included as the outcome is standardized for child sex. The association between the maternal interpregnancy weight change with risk of childhood overweight and obesity in the second child was examined by fitting generalised linear models predicting each of the two binary outcomes (overweight or obesity) to categories of BMI gain (with stable BMI as the referent category) and covariates using a log link [31] (i.e. log-binomial regression). This was analysed first in the whole sample and then stratified by baseline maternal BMI category. A statistical significance level of 0.05 with 95% confidence intervals was used in the models.

Covariate adjustments for downstream consequences of exposures (e.g. mediators) has long been known to be a potential source of bias [32], particularly in obstetrics [33] and perinatal epidemiology [34] where adjustments for factors such as birthweight and gestational age are common and may lead to paradoxical findings. We investigated the sensitivity of our original models such collider stratification bias by using inverse probability weighting to balance the distribution of exposure and mediators before any covariate adjustments. Weights were calculated by estimating separate propensity scores for the exposure and each mediator based on their respective confounders specified in the DAG and taking their inverse. Each subject was then weighted by the product of exposure and mediator weights in corresponding analyses. Under the strong assumption that all exposure- and mediator- outcome confounding is properly adjusted with no meaningful interactions, the resulting estimates correspond to the effect of interpregnancy weight change in a population where individuals all have similar likelihood of attaining observed mediator values. That is, if assumptions are fulfilled, such models can be used to estimate of the remaining effect of interpregnancy weight gain on second child overweight if interventions on pregnancy and birth outcomes could be taken.

All analyses were performed using Stata 15 [35].

Ethical considerations
Data were anonymised by the data holders before being accessed by the research team. Ethics approval was granted by the University of Southampton Faculty of Medicine Ethics Committee (ID 24433) and Health Research Authority (HRA) (IRAS 242031).

RESULTS
Information on the first and second singleton live birth pregnancies and BMI of second child at 4–5 years was available for 4789 women. Of these, 42.7% women remained weight stable, 33.5% exhibited MWG (1–3 kg/m²) and 23.7% exhibited SWG (>3 kg/m²). Mean maternal BMI at second pregnancy was 24.1 kg/m² (standard deviation (SD) 4.1) in women who remained weight stable, 26.1 kg/m² (SD 4.5) in women with MWG and 31.1 kg/m² (SD 5.8) in women with SWG (Table 1). There was a significant increase in the proportion of women with overweight in the second pregnancy but the proportion with obesity nearly tripled from first (18.3%) to second (51.0%) pregnancy in women with SWG. Thirty percent of women who remained weight stable had overweight or obesity at second pregnancy compared to 50.6% with MWG and 88.2% with SWG.

Women with SWG were more likely to be younger, smokers, unemployed and of lower educational attainment and have longer interval between pregnancies compared to those who remained weight stable between pregnancies. Women with SWG were also more likely to have overweight and obesity at both first and second pregnancies.

The prevalence of overweight and obesity at 4–5 years in the second-born child increased from 15.9% in women who were normal weight at second pregnancy to 33.4% in women with obesity at the start of second pregnancy (Fig. 2). The prevalence of overweight and obesity in the second-born child increased from 19.1% in women who remained weight stable between pregnancies to 21.5% in women with MWG to 28.3% in women with SWG. A higher proportion of second-born children of women with SWG had obesity (12.0%) compared to children of women who remained weight stable (6.9%) or with MWG (7.5%). Children of women with SWG were at increased risk of childhood overweight and obesity (>95th centile) (adjusted relative risk (aRR) 1.17, 95% confidence interval (CI) 1.02–1.34) compared to remaining weight stable (Table 2). The relationship was attenuated on adjusting for birthweight, gestational age at birth, gestational diabetes in second pregnancy and breastfeeding status in second pregnancy (aRR 1.08, 95% CI 0.94–1.24). The attenuation was mainly from the
Table 1. Maternal and birth characteristics categorised by maternal weight change from the first live birth pregnancy for the period of January 2003–September 2017, University Hospital Southampton NHS Foundation Trust, Hampshire, England.

|                      | Weight stable (<1 kg/m²) | Moderate weight gain (1–3 kg/m²) | Substantial weight gain (≥3 kg/m²) | p*  |
|----------------------|--------------------------|---------------------------------|-----------------------------------|-----|
| N                    | 2047                     | 1605                            | 1137                              |     |
| Maternal age at first pregnancy, years (mean ± SD) | 27.1 ± 5.2               | 26.2 ± 5.3                      | 23.7 ± 5.4                        | <0.001 |
| Maternal age at second pregnancy, years (mean ± SD) | 29.8 ± 5.2               | 29.1 ± 5.3                      | 27.0 ± 5.5                        | <0.001 |
| First pregnancy booking appointment, weeks (mean ± SD) | 11.3 ± 2.5               | 11.4 ± 2.6                      | 11.4 ± 2.8                        | 0.78 |
| Second pregnancy booking appointment, weeks (mean ± SD) | 10.9 ± 2.3               | 11.2 ± 2.3                      | 10.9 ± 2.5                        | 0.002 |
| Maternal BMI at first pregnancy booking, kg/m² (mean ± SD) | 24.0 ± 4.1               | 24.3 ± 4.4                      | 26.0 ± 5.1                        | <0.001 |
| Maternal BMI at second pregnancy booking, kg/m² (mean ± SD) | 24.1 ± 4.1               | 26.1 ± 4.5                      | 31.1 ± 5.8                        | <0.001 |
| Maternal smoking status at first pregnancy booking (%, 95% CI) | 70.2 (68.2 to 72.2)      | 65.4 (63.0 to 67.7)             | 48.5 (45.6 to 51.5)               | <0.001 |
| Maternal smoking status at second pregnancy booking (%, 95% CI) | 70.0 (67.9 to 71.9)      | 49.3 (46.9 to 51.8)             | 11.8 (10.0 to 13.8)               | <0.001 |
| Maternal education (%, 95% CI) | 70.2 (68.2 to 72.2)      | 65.4 (63.0 to 67.7)             | 48.5 (45.6 to 51.5)               | <0.001 |
| Maternal smoking status at second pregnancy booking (%, 95% CI) | 70.0 (67.9 to 71.9)      | 49.3 (46.9 to 51.8)             | 11.8 (10.0 to 13.8)               | <0.001 |
| Maternal education (%, 95% CI) | 24.4 (22.6 to 26.3)      | 28.8 (26.6 to 31.1)             | 35.4 (32.7 to 38.3)               | <0.001 |
| Maternal smoking status at second pregnancy booking (%, 95% CI) | 24.4 (22.6 to 26.3)      | 28.8 (26.6 to 31.1)             | 35.4 (32.7 to 38.3)               | <0.001 |
| Maternal employment status at first pregnancy (% 95% CI) | 89.0 (87.6 to 90.3)      | 84.6 (82.8 to 86.3)             | 74.1 (71.5 to 76.7)               | <0.001 |
| Maternal employment status at second pregnancy (% 95% CI) | 89.0 (87.6 to 90.3)      | 84.6 (82.8 to 86.3)             | 74.1 (71.5 to 76.7)               | <0.001 |
| Maternal employment status at first pregnancy (% 95% CI) | 85.7 (84.1 to 87.3)      | 81.4 (79.8 to 83.1)             | 71.0 (68.5 to 73.6)               | <0.001 |
| Maternal employment status at second pregnancy (% 95% CI) | 85.7 (84.1 to 87.3)      | 81.4 (79.8 to 83.1)             | 71.0 (68.5 to 73.6)               | <0.001 |
| Maternal education (%, 95% CI) | 40.6 (38.5 to 42.8)     | 40.9 (38.5 to 43.4)             | 47.9 (45.0 to 50.9)               | <0.001 |
| University degree or above | 40.6 (38.5 to 42.8)     | 40.9 (38.5 to 43.4)             | 47.9 (45.0 to 50.9)               | <0.001 |
| Maternal employment status at first pregnancy (% 95% CI) | 40.6 (38.5 to 42.8)     | 40.9 (38.5 to 43.4)             | 47.9 (45.0 to 50.9)               | <0.001 |
| Maternal employment status at second pregnancy (% 95% CI) | 40.6 (38.5 to 42.8)     | 40.9 (38.5 to 43.4)             | 47.9 (45.0 to 50.9)               | <0.001 |
adjustment for birthweight (Supplementary Table 1). This pattern for SWG was similar in the subgroup with obesity at the start of their first pregnancy (aRR 1.34, 95% CI 1.02–1.78, and aRR 1.25, 95% CI 0.94–1.64, respectively). A similar pattern was observed in women who were normal weight (aRR 1.16, 95% CI 0.93–1.45, and aRR 1.07, 95% CI 0.85–1.34) at the start of their first pregnancy. There was no evidence of association between MWG weight gain and childhood overweight and obesity. The association between SWG and childhood overweight and obesity persist when conducted using IPW (Supplementary Table 2).

Both MWG and SWG were associated with increased risk of childhood obesity (≥95th centile) only in women who were normal weight at first pregnancy (aRR 1.55, 95% CI 0.99–2.42 for MWG and aRR 1.74, 95% CI 1.11–2.73 for SWG) (Table 3). The relationship remained on adjusting for mediators of birthweight, gestational age at birth, gestational diabetes in second pregnancy and breastfeeding status in second pregnancy (aRR 1.74, 95% CI 1.07–2.83 for MWG and aRR 1.87, 95% CI 1.18–3.01 for SWG). There was no evidence of association between interpregnancy weight gain and childhood obesity in women with overweight or obesity at first pregnancy; however, the number of outcome events in this group were quite small. Analysis using IPW found the same association with childhood obesity in women who were normal weight at first pregnancy with SWG (Supplementary Table 3).

Fig. 2 Prevalence of overweight and obesity in the second child at 4–5 years by maternal BMI category at second pregnancy. Prevalence of overweight and obesity by maternal BMI category.

调整生体重（补充表1）。该模式对SWG在在子代出生时体重正常者（aRR 1.34, 95% CI 1.02–1.78, and aRR 1.25, 95% CI 0.94–1.64, respectively）。一个相似的模式在正常体重的女性中被观察到（aRR 1.16, 95% CI 0.93–1.45, and aRR 1.07, 95% CI 0.85–1.34）在她们的第一孕期间。没有证据表明MWG会增加儿童超重和肥胖。chw的体重与肥胖之间没有证据。
Table 2. Associations between risk of overweight and obesity (85th centile) in the second child at age 4–5 years and change in maternal body mass index (BMI) between pregnancies as measured at the first antenatal visit of each pregnancy stratified by BMI category in the first pregnancy.

| Maternal BMI change (categorised) | Full sample | Normal weight at first pregnancy | Overweight at first pregnancy | Obesity at first pregnancy | n of cases | n of cases | n of cases | RR* | 95% CI |
|----------------------------------|-------------|---------------------------------|-----------------------------|---------------------------|------------|-----------|-----------|------|--------|
| Weight stable (>{-1 to <1 kg/m²})| 1605, 345   | 1.13                            | 0.99 to 1.28                | 1.17                      | 1050, 188  | 1.17      | 1.09 to 1.21 | 1.15 | 0.95 to 1.38 |
| Model 1                          | 1.06        | 1.02 to 1.16                    | 1.02 to 1.17                | 1.02 to 1.17              | 383, 96    | 1.05      | 1.03 to 1.07 | 1.05 | 0.93 to 1.15 |
| Model 2                          | 1.01        | 1.04 to 1.24                    | 1.03 to 1.15                | 1.02 to 1.14              | 181, 60    | 1.04      | 1.02 to 1.07 | 1.00 | 0.94 to 1.07 |
| Model 3                          | 1.08        | 1.09 to 1.26                    | 1.08 to 1.27                | 1.09 to 1.27              | 228, 111   | 1.08      | 1.06 to 1.10 | 1.07 | 0.93 to 1.24 |
| Model 4                          | 1.08        | 1.10 to 1.27                    | 1.08 to 1.27                | 1.09 to 1.27              | 183, 60    | 1.08      | 1.06 to 1.10 | 1.07 | 0.93 to 1.25 |

Model 1: adjusted for maternal age at first pregnancy, ethnicity, highest educational qualification, smoking status at first and second preganancy, employment status at first and second pregnancy, gestational age at booking appointment, baseline BMI, gestational diabetes in second pregnancy, interpregnancy interval, birthweight, gestational age at birth and breastfeeding status for second pregnancy.

Model 2: adjusted for maternal age at first pregnancy, ethnicity, highest educational qualification, smoking status at first and second preganancy, employment status at first and second pregnancy, gestational age at booking appointment, baseline BMI, gestational diabetes in second pregnancy, interpregnancy interval, birthweight, gestational age at birth and breastfeeding status for second pregnancy.

Model 3: adjusted for maternal age at first pregnancy, ethnicity, highest educational qualification, smoking status at first and second preganancy, employment status at first and second pregnancy, gestational age at booking appointment, baseline BMI, gestational diabetes in second pregnancy, interpregnancy interval, birthweight, gestational age at birth and breastfeeding status for second pregnancy.

Model 4: adjusted for maternal age at first pregnancy, ethnicity, highest educational qualification, smoking status at first and second preganancy, employment status at first and second pregnancy, gestational age at booking appointment, baseline BMI, gestational diabetes in second pregnancy, interpregnancy interval, birthweight, gestational age at birth and breastfeeding status for second pregnancy.

Bold values indicate statistical significance.

There is increasing evidence of the importance of the preconception and pregnancy periods on long-term health. A suggested approach to improving preconception health is to promote health of the population more broadly with targeting of women and partners planning a pregnancy [43–45]. It is important to engage with women during the interpregnancy period to optimise their and their children’s health and address the barriers.
Table 3. Associations between risk of obesity (95th centile) in the second child at age 4–5 years and change in maternal body mass index (BMI) between pregnancies as measured at the first antenatal visit of each pregnancy stratified by BMI category in the first pregnancy.

| Maternal BMI change (categorised) | Full sample | Normal weight at first pregnancy | Overweight at first pregnancy | Obesity at first pregnancy |
|----------------------------------|-------------|---------------------------------|-----------------------------|---------------------------|
|                                  | n           | Relative risk, (RR)             | 95% CI                      | n                         | RR   | 95% CI  | n   | RR   | 95% CI |
| Weight stable (> – 1 to <1 kg/m²) |             |                                 |                             |                           |      |      |      |      |      |
| Unadjusted                       | 1605, 120   | 1.08                            | 0.85 to 1.36                | 1050, 64                   | 1.37 | 0.98 to 1.92 | 383, 34 | 0.81 | 0.53 to 1.23 |
| Model 1                          | 0.97        | 0.75 to 1.25                    | 1.55                        | 0.99 to 2.42               | 0.86 | 0.50 to 1.50 | 172, 22 | 0.75 | 0.45 to 1.24 |
| Model 2                          | 0.93        | 0.70 to 1.22                    | 1.74                        | 1.07 to 2.83               | 0.69 | 0.35 to 1.36 | 368, 52 | 0.74 | 0.41 to 1.33 |
| Moderate weight gain (1–3 kg/m²) |             |                                 |                             |                           |      |      |      |      |      |
| Unadjusted                       | 1137, 137   | 1.74                            | 1.39 to 2.17                | 552, 53                    | 2.16 | 1.52 to 3.06 | 377, 41 | 0.99 | 0.67 to 1.47 |
| Model 1                          | 1.26        | 0.96 to 1.64                    | 1.74                        | 1.11 to 2.73               | 0.87 | 0.52 to 1.47 | 208, 43 | 1.21 | 0.80 to 1.83 |
| Model 2                          | 1.15        | 0.88 to 1.51                    | 1.87                        | 1.18 to 3.01               | 0.81 | 0.51 to 1.30 | 172, 22 | 1.28 | 0.70 to 2.35 |
| Substantial weight gain (≥3 kg/m²)|             |                                 |                             |                           |      |      |      |      |      |
| Unadjusted                       |             |                                 |                             |                           |      |      |      |      |      |
| Model 1                          |             |                                 |                             |                           |      |      |      |      |      |
| Model 2                          |             |                                 |                             |                           |      |      |      |      |      |

Model 1: adjusted for maternal age at first pregnancy, ethnicity, highest educational qualification, smoking status at first and second pregnancy, employment status at first pregnancy and breastfeeding status at first pregnancy.

Model 2: adjusted for maternal age at first pregnancy, ethnicity, highest educational qualification, smoking status at first pregnancy, employment status at first pregnancy, gestational age at booking, baseline BMI, gestational diabetes in first pregnancy, interpregnancy interval, birthweight, gestational age at birth and breastfeeding status for second pregnancy.

*Generalised linear model with log link and robust variance estimator used to derive RR.

**Bold values indicate statistical significant results.**
weight women who gained weight between pregnancies were more likely to have obesity at the start of primary school. The interpregnancy period between two pregnancies is a preconception intervention opportunity for subsequent pregnancies as women and their families have intensive contact with healthcare professionals after birth of a child. There is a need to support return to pre-pregnancy weight in normal weight women and weight loss in women with overweight and obesity.

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Study concept (NZ and NAA), study design (NZ, JYH, EJT and NAA), acquisition and interpretation of the data (NZ and NAA), data cleaning and management (NZ), statistical analysis (NZ), drafting of the manuscript (NZ), revising for content and approval of final version before submission (all authors). NAA is the project’s PI.

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COMPETING INTERESTS
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