Weight gain trajectories patterns from pregnancy to early postpartum: identifying women at risk and timing to prevent weight regain

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Research Article

Keywords: weight gain, maternal, pregnancy, postpartum, trajectories, women of reproductive age

Posted Date: March 23rd, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1416430/v1

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Abstract

Background

Woman’s weight changes during pregnancy and postpartum contribute to obesity and health outcomes later in life. This study aimed to identify and characterize weight change trajectories from pregnancy to one year postpartum among adult women.

Methods

We used data from an ongoing cohort of healthy adult women (n = 819) with singleton pregnancies from 2007–2011. Sociodemographic data, pre-pregnancy body weight, and sedentary and breastfeeding practices were collected. We applied a group-based trajectory modeling to distinguish weight change measured in the second and third trimesters of pregnancy and at one month, six, and 12 months postpartum. Multinomial regression models were run to characterize each trajectory.

Results

We identified six weight change trajectories with the main difference in the patterns followed after one month of delivery. One in three women (36.7%), classified in some of the three postpartum weight gain trajectories, started to gain weight at the second or third trimester of the first year postpartum. Women who followed some of these trajectories were more likely to have higher age, obesity before pregnancy, < 10 years of schooling, and partner, compared with women (10.7%, n = 87) in a postpartum sustained-fast-lost-weight trajectory (p < 0.05).

Conclusions

Women with obesity before pregnancy have a higher odd of regained gestational weight after delivery without reaching their pre-pregnancy weight. The first six months postpartum are key to establishing obesity prevention strategies. Further research is needed to evaluate the effect of the interventions that prevent substantial weight gain through reproductive years in high-risk women.

Background

Weight gain is expected during pregnancy to promote adequate fetal development and growth [1, 2]. The weight gain resulting from fetal components and body water is lost in the first weeks of postpartum; therefore, the remaining gained weight corresponds to the increase in maternal fat mass [1–4]. Gestational fat mass accretion may be used as body storage to support breastfeeding [5]. Even so, a higher fat mass accretion during pregnancy may influence postpartum weight retention [6].
Following pregnancy, most women do not return to their pre-pregnancy weight [7–9]. Excessive weight gain during pregnancy and postpartum is a risk factor for obesity in later years [6]. The interpregnancy increase of body weight is also associated with adverse perinatal outcomes in the subsequent pregnancy regardless of body mass index (BMI) category, such as gestational diabetes mellitus, preeclampsia, and large for gestational age [10].

Gestational weight and postpartum weight retention vary significantly among women [6]. In addition, some women gain weight during postpartum even when they have not reached their pre-pregnancy weight. These observations suggest heterogeneity in the distribution of weight change during these reproductive moments. The latter is unclear since most studies have considered the average gestational weight gained, the percentage of women with excessive gestational weight gain, and the average weight retention in some postpartum moment [6–9].

Pregnancy and postpartum are critical periods to establish strategies to impact women's and children's health. In the non-pregnant population, identifying BMI trajectories has shown an advantage in highlighting timely periods to develop obesity prevention strategies and identifying vulnerable or high-risk groups [11]. Studies with a trajectory approach have examined health risks among women of reproductive age according to weight gain throughout the life course. Kim et al. observed that women with a medium body shape in early adulthood (age 18 years) and a weight gain of more than 20 kilograms (kg) in later adulthood were at high risk of developing the non-alcoholic fatty liver disease (NAFLD) compared to women who maintained a medium body shape. Additionally, women who were lean in early adulthood but gained weight in the later years were also at increased risk of NAFLD [12]. Gaskins et al. reported a negative link between an increase of 10-kg during adulthood and live birth in women with assisted reproductive [13].

The purpose of this study was to identify trajectories of weight change from pregnancy to one year postpartum. We also sought to characterize these trajectories according to sociodemographic data, pre-pregnancy BMI, and postpartum behaviors.

**Methods**

**Study Sample**

This present study is a secondary analysis of data from the ongoing Programming Research in Obesity, Growth, Environmental, and Social Stress (PROGRESS) pregnancy cohort in Mexico City. Details of PROGRESS are published elsewhere [14]. Briefly, pregnant women with less than 20 weeks of gestation were recruited from four prenatal care clinics within the Mexican Social Security Institute (IMSS, by its acronym in Spanish). Women were eligible for participation if they were 18 years or older and planned to reside in Mexico City for the next three years. Exclusion criteria were cardiovascular or renal disease, use of steroids or antiepileptic drugs, and daily alcohol consumption. Women provided written informed consent. The Institutional Review Boards from the National Institute of Public Health in Mexico, and the Icahn School of Medicine at Mount Sinai and the Harvard TH Chan School of Public Health in the United States (US) approved the study protocol.
Women attended study visits at baseline (< 20 weeks of gestation) and during the third trimester (27–36 weeks of gestation) as well as three times during the first year postpartum (one month, six months, and 12 months postpartum). There were 956 women with live singleton births. For this analysis, we excluded women who had a subsequent pregnancy within the following year of the index pregnancy (n = 9), who did not return for follow-up visits (n = 8), or who delivered preterm (less than 37 weeks of gestation, n = 120). We excluded women with preterm delivery since these women had incomplete weight trajectories and a higher probability of having adverse perinatal outcomes, which may influence weight change patterns [15]. The final analytic sample was 819 women.

Measures

At baseline, trained social workers administered a questionnaire to collect maternal sociodemographic characteristics. We used the Mexican Association of Marketing Research and Public Opinion Index (AMAI), a 13x6 battery based on family possessions, living conditions, and education, to categorize six socioeconomic status (SES) levels ranging from lowest (1) to highest (6) SES within the cohort [16]. We reclassified these categories as low (1, 2), medium (3), and high (4, 5, 6). Women self-reported their pre-pregnancy weight (kg) at six months prior to pregnancy. To account for potential recall bias [17], we adjusted these self-reported weights using an imputation procedure. Maternal pre-pregnancy weight was predicted using a longitudinal model (linear mixed-effects) with repeated weight data from six months before pregnancy to the third-trimester visit. We used 10-fold cross-validation to test the model’s performance based on those women with weights (n = 87) close to their last menstrual period (LMP). Root mean squared error of 3.21 kg was considered as a measure of predictive accuracy [18]. We calculated pre-pregnancy BMI using adjusted pre-pregnancy weight (kg) and measured height (m) at the baseline visit. Pre-pregnancy BMI was classified using World Health Organization criteria (WHO, 2005): underweight (< 18.5 kg/m$^2$), healthy weight (18.5–24.9 kg/m$^2$), overweight (25.0–29.9 kg/m$^2$), and obesity (≥ 30 kg/m$^2$).

Trained personnel measured women's weight (without shoes and clothes) during pregnancy (baseline and third trimester visits) and the postpartum (one-, six-, and 12-month visits). Weight was measured using a combined mechanical scale and stadiometer (Health-O-Meter; Scaleomatics INC, Cleveland, OH) to the nearest 100 grams. Following the Institute of Medicine’s (IOM, 2009) recommendations of gestational weight gain rate [13], we classified women's gestational weight gain at the second and third trimesters of pregnancy (considering pre-pregnancy BMI and gestational age) as insufficient, adequate, and excessive. Gestational age was defined according to the LMP and corroborated with the Capurro method. In 33 cases where gestational age at birth differed by more than two weeks with LMP, we adjusted gestational age weeks.

At each study visit (except 12 months postpartum), women reported the average daily time spent in physical activities, such as walking, and sedentary behaviors, such as watching television or reading. Physical activity was categorized as inactive (< 20 minutes per day), minimally active (20–60 minutes per day), and active (> 60 minutes per day). Sedentary behavior was categorized as non-sedentary (< 120 minutes per day), moderate sedentary (120–180 minutes per day), and sedentary (> 180 minutes per day) [19]. At one and six months postpartum, women reported if they were currently breastfeeding their infant (yes or no) and
if they were exclusively providing breast milk (yes or no). Breastfeeding was categorized as not breastfeeding, not exclusive breastfeeding, and exclusive breastfeeding. The intensity of breastfeeding was defined as the daily number of times a woman breastfed her baby at one and six months postpartum.

**Statistical analysis**

We first explored the maternal weight’s probability distribution at five points in time: two during pregnancy and three during the first year postpartum. Weeks lapsed were counted since LMP: baseline visit at $18 \pm 1.3$ weeks (second trimester of pregnancy), $31.7 \pm 1.4$ weeks (third trimester of pregnancy), $43.7 \pm 1.3$ weeks (one month postpartum), $65.7 \pm 1.3$ weeks (six months postpartum), and $92.0 \pm 1.5$ weeks (12 months postpartum). We transformed weeks into the log scale to deal with the uneven time lapses between consecutive measurements. As part of the exploratory analysis, we also studied the behavior of maternal variables and evaluated for potential selection bias comparing characteristics between women included and excluded from the analysis.

We constructed the possible weight trajectories and assessed their shape. Group-Based Trajectory Models were used to identify women following similar weight change trajectories [20]. This type of model forms a family of semiparametric statistical techniques that have been used to analyze longitudinal data in clinical fields. This approach helps us to distinguish different patterns and their appropriate polynomial order beyond a linear association.

We considered a model with time points varying among women, a normal distribution for the response, and trajectory shapes that followed a cubic polynomial. Two to six types of trajectories were evaluated. The optimum number of types of trajectories was chosen based on the lower Bayesian Information Criterion (BIC), probabilities of membership (>90%), and odds of correct classification (>5). Given the above optimal number, each woman was classified in the trajectory of her highest probability; thus, women in the sample formed as many groups as types of trajectories identified.

Additionally, we identified the main characteristics of the women's membership in the respective trajectories using multinomial regression models. We used the first trajectory as a reference since it followed a continuous postpartum weight loss. Because a higher pre-gestational BMI in women could result from older age or higher parity, we tested first and second-order interactions.

**Results**

Women had a mean age of $27 \pm 5.4$ years and $11.8 \pm 2.8$ years of schooling at enrollment. Most women had at least one child before the current pregnancy (62.7%), reported living with a partner (81.2%), and were classified as low SES (51.8%). Mean pre-pregnancy BMI was $26.7 \pm 4.3$ kg/m$^2$. Prevalence of underweight, healthy weight, overweight, and obesity were 1.2%, 42.7%, 38.5%, and 17.6%, respectively. Out of the women included, 86.6% ($n = 701$), 74.7% ($n = 612$), 67.8% ($n = 555$), and 52.9% ($n = 434$) returned to the visit at third trimester of pregnancy, one month postpartum, six months postpartum, and 12 months postpartum, respectively. Compared with women with weight data for all visits ($n = 306$), women with missing data were
similar for most sociodemographic characteristics, except pre-pregnancy BMI. However, there were no differences in the proportions of women with pre-pregnancy overweight or obesity.

We identified six distinct trajectories of overall weight change from the second trimester of pregnancy to 12 months postpartum, each of these with two-time intervals (Fig. 1). The first time-interval corresponded with weight change during pregnancy and the first month postpartum. The second interval corresponded with weight change after the first month postpartum. As expected, all trajectories showed weight gain during pregnancy and substantial weight loss in the first month postpartum; however, they differed in the magnitude of such weight change. In the second time-interval, in addition to the differences in the magnitude of weight change, two distinct groups could be observed. In the first group, women continued to lose weight, while in the other, women gained weight.

We named the trajectories according to the magnitude of weight increase and loss or gain in these two-time intervals observed. Trajectory 1 corresponds to a high weight gain during pregnancy and a fast weight loss along postpartum (HG-FL); trajectory 2 refers to a moderate weight gain during pregnancy and a moderate loss along postpartum (MG-ML); trajectory 3 relates to a lower weight gain during pregnancy and a slow loss along postpartum (LG-SL). In the second group, trajectory 4 corresponds to a high weight gain during pregnancy and a moderate gain postpartum (HG-MG); trajectory 5 corresponds to a high weight gain during pregnancy and a high gain postpartum (HG-HG); and finally, trajectory 6 corresponds to a moderate weight gain during pregnancy and a slow gain postpartum (MG-SG). Most women were classified in trajectory LG-SL (28.8%), followed by trajectories MG-ML (23.8%), HG-MG (20.6%), HG-HG (11.7%), HG-FL (10.7%), and MG-SG (4.4%).

The sociodemographic characteristics of women for each type of trajectory are presented in Table 1. On average, the pre-pregnancy BMI of women in HG-FL and MG-ML trajectories corresponded to a healthy weight; LG-SL and HG-HG to overweight; HG-MG and MG-SG to obesity. Concerning women in HG-FL and MG-ML, none of them had obesity before pregnancy, while in MG-SG, most of them did.
## Table 1
Characteristics of women according to the type of trajectory

|                      | All women | 1 (HG-FL) n = 87 | 2 (MG-ML) n = 195 | 3 (LG-SL) n = 236 | 4 (HG-MG) n = 169 | 5 (HG-HG) n = 96 | 6 (MG-SG) n = 36 |
|----------------------|-----------|------------------|-------------------|-------------------|------------------|-----------------|-----------------|
| **Age, years**¹      |           |                  |                   |                   |                   |                 |                 |
|                      | 27.1 ± 5.5| 25.0 ± 4.6       | 27.1 ± 5.7        | 27.3 ± 5.4        | 27.6 ± 5.1       | 27.5 ± 6.0      | 27.3 ± 5.1      |
| **Schooling, years**²|           |                  |                   |                   |                   |                 |                 |
| < 10 years           |           |                  |                   |                   |                   |                 |                 |
|                      | 345 (42.1%)| 46 (52.9%)       | 90 (46.1%)        | 86 (36.4%)        | 75 (44.4%)       | 31 (32.3%)      | 17 (47.2%)      |
| ≥ 10 years           | 474 (57.9%)| 41 (47.1%)       | 105 (53.9%)       | 150 (63.6%)       | 94 (55.6%)       | 65 (67.7%)      | 19 (52.8%)      |
| **Parity**           |           |                  |                   |                   |                   |                 |                 |
|                      | 2 (2)     | 2 (2)            | 2 (2)             | 2 (2)             | 2 (2)            | 2 (2)           | 2 (2)           |
| **Nulliparous**      |           |                  |                   |                   |                   |                 |                 |
|                      | 305 (37.2%)| 34 (39.1%)       | 69 (35.4%)        | 94 (39.8%)        | 58 (34.3%)       | 36 (37.5%)      | 14 (38.9%)      |
| 1–2 births           | 390 (47.6%)| 43 (49.4%)       | 98 (50.3%)        | 111 (47.0%)       | 73 (43.2%)       | 49 (51.0%)      | 16 (44.4%)      |
| ≥ 3 births           | 124 (15.2%)| 10 (11.5%)       | 28 (14.3%)        | 38 (22.5%)        | 11 (11.5%)       | 6 (16.8%)       |                 |
| **Living with partner**|         |                  |                   |                   |                   |                 |                 |
| Yes                  | 665 (81.2%)| 64 (73.6%)       | 160 (82.1%)       | 189 (80.1%)       | 142 (84.0%)      | 83 (86.5%)      | 27 (75%)        |
| No                   | 154 (18.8%)| 23 (26.4%)       | 35 (17.9%)        | 47 (19.9%)        | 27 (16.0%)       | 13 (13.5%)      | 9 (25%)         |
| **Working outside home**|         |                  |                   |                   |                   |                 |                 |
| Yes                  | 557 (68.0%)| 59 (67.8%)       | 122 (62.6%)       | 175 (74.2%)       | 120 (71.0%)      | 63 (65.6%)      | 18 (50.0%)      |
| No                   | 262 (32.0%)| 28 (32.2%)       | 73 (37.4%)        | 31 (25.8%)        | 49 (29.0%)       | 33 (34.4%)      | 18 (50.0%)      |

¹Mean ± SD. ²Median (interquartile range). HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum. Women’s weight was classified using WHO criteria: underweight (< 18.5 kg/m²), healthy weight (18.5, 24.9 kg/m²), overweight (25.0, 29.9 kg/m²), and obesity (≥ 30 kg/m²).
|                    | All women | 1 (HG-FL) n = 87 | 2 (MG-ML) n = 195 | 3 (LG-SL) n = 236 | 4 (HG-MG) n = 169 | 5 (HG-HG) n = 96 | 6 (MG-SG) n = 36 |
|--------------------|-----------|------------------|-------------------|-------------------|-------------------|----------------|----------------|
| **Low**            | 424 (51.8%) | 52 (59.8%)       | 111 (56.9%)       | 104 (44.1%)       | 83 (49.1%)        | 56 (58.3%)     | 18 (50.0%)     |
| **Medium**         | 307 (37.5%) | 27 (31.0%)       | 68 (34.9%)        | 97 (41.1%)        | 72 (42.6%)        | 28 (29.2%)     | 15 (41.7%)     |
| **High**           | 88 (10.7%)  | 8 (9.2%)         | 16 (8.2%)         | 35 (14.8%)        | 14 (8.2%)         | 12 (12.5%)     | 3 (8.3%)       |

**Anthropometric**

|                     |          |                  |                  |                  |                  |                |                |
|---------------------|----------|------------------|------------------|------------------|------------------|----------------|----------------|
| **Height, m**       | 1.55 ± 0.1 | 1.50 ± 0.1       | 1.53 ± 0.1       | 1.55 ± 0.1       | 1.56 ± 0.1       | 1.58 ± 0.1     | 1.58 ± 0.1     |
| **Pre-pregnancy weight, kg** | 63.2 ± 11.1 | 47.5 ± 3.8       | 54.7 ± 3.1       | 61.5 ± 3.9       | 69.2 ± 3.7       | 78.1 ± 4.5     | 89.3 ± 5.4     |
| **Pre-pregnancy BMI, kg/m²** | 26.2 ± 4.2   | 20.1 ± 1.7       | 23.3 ± 1.8       | 25.6 ± 2.1       | 28.4 ± 2.1       | 31.2 ± 2.6     | 35.6 ± 3.3     |

**Underweight** | 10 (1.2%) | 10 (11.5%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) | 0 (0%) |

**Healthy weight** | 359 (42.7%) | 77 (88.5%) | 164 (84.1%) | 98 (41.5%) | 9 (5.3%) | 2 (2.1%) | 0 (0%) |

**Overweight** | 315 (38.5%) | 0 (0%) | 35 (15.9%) | 131 (55.5%) | 123 (72.8%) | 29 (30.2%) | 1 (2.8%) |

**Obesity** | 144 (17.6%) | 0 (0%) | 0 (0%) | 7 (3%) | 37 (21.9%) | 65 (67.7%) | 35 (97.2%) |

1Mean ± SD. 2Median (interquartile range). HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum. Women’s weight was classified using WHO criteria: underweight (< 18.5 kg/m²), healthy weight (18.5, 24.9 kg/m²), overweight (25.0, 29.9 kg/m²), and obesity (≥ 30 kg/m²).

Based on a crude multinomial regression model, Table 2 presents the probability of following each trajectory related to relevant sociodemographic characteristics. Being in the HG-FL trajectory decreased as pre-pregnancy BMI (kg/m²) increased. Compared to women in this trajectory, women in all other trajectories were older (P< 0.01). Women with < 10 years of schooling had a lower probability of membership in LG-SL or HG-HG trajectories (P< 0.01). Also, the probability of membership in HG-HG was the lowest if women were living with a partner (P< 0.05). We observed a higher probability of membership in LG-SL in women with medium and high SES (P< 0.10). On the contrary, women with more than two children previous to
current pregnancy and not working outside the home were more likely to be in the HG-MG and MG-SG trajectory, respectively ($P < 0.10$). We did not observe an interaction between pre-pregnancy BMI, age, and parity on the membership of being in one or another trajectory ($P < 0.30$).

Table 2  
Probability of membership in each trajectory according to sociodemographic characteristics

|                          | MG-ML $^1$               | LG-SL $^1$               | HG-MG $^1$               | HG-HG $^1$               | MG-SG $^1$               |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| **Age, years**           | 1.08 [1.03–1.14]$^2$     | 1.08 [1.04–1.14]$^2$     | 1.10 [1.05–1.16]$^2$     | 1.09 [1.04–1.16]$^2$     | 1.09 [1.01–1.18]$^2$     |
| **Schooling, years**     | 1.03 [0.94–1.13]         | 1.08 [0.98–1.18]$^3$     | 1.08 [0.98–1.17]         | 1.09 [0.99–1.22]$^3$     | 1.09 [0.95–1.25]         |
| **< 10 vs ≥ 10**         | 0.76 [0.46–1.27]         | 0.51 [0.31–0.84]$^2$     | 0.71 [0.42–1.19]         | 0.43 [0.23–0.77]$^2$     | 0.79 [0.36–1.73]         |
| **Parity**               | 1.09 [0.87–1.35]         | 0.99 [0.80–1.22]         | 1.17 [0.94–1.47]         | 1.02 [0.80–1.31]         | 1.04 [0.74–1.45]         |
| **1–2 vs nulliparous**   | 1.12 [0.65–1.93]         | 0.93 [0.55–1.58]         | 0.99 [0.56–1.75]         | 1.07 [0.57–2.01]         | 0.90 [0.38–2.11]         |
| **≥ 3 vs nulliparous**   | 1.37 [0.60–3.16]         | 1.12 [0.49–2.52]         | 2.22 [0.98–5.03]$^3$     | 1.03 [0.39–2.75]         | 1.45 [0.44–4.78]         |
| **Without partner vs partner** | 0.61 [0.33–1.10]$^3$     | 0.69 [0.38–1.22]         | 0.52 [0.28–0.99]$^4$     | 0.43 [0.20–0.92]$^4$     | 0.92 [0.38–2.26]         |
| **Working outside home (yes vs no)** | 0.79 [0.46–1.35]         | 1.36 [0.79–2.32]         | 1.16 [0.66–2.03]         | 0.90 [0.48–1.67]         | 0.47 [0.21–1.05]$^3$     |
| **Medium SES vs low SES** | 1.17 [0.67–2.05]         | 1.79 [1.04–3.08]$^4$     | 1.67 [0.95–2.93]$^3$     | 0.96 [0.50–1.84]         | 1.60 [0.70–3.67]         |
| **High SES vs low SES**  | 0.93 [0.37–2.32]         | 2.19 [0.94–5.05]$^3$     | 1.09 [0.43–2.79]         | 1.39 [0.53–3.67]         | 1.08 [0.25–4.53]         |
| **Pre-pregnancy BMI, kg/m²** | 2.2 [1.8–2.70]$^2$       | 4.2 [3.3–5.34]$^2$       | 7.6 [5.8–9.9]$^2$        | 12.51 [9.3–16.9]$^2$     | 22.1 [15.4–31.6]$^2$     |

$^1$ Data are OR [95% CI] from crude multinomial regression models. Group of reference: trajectory 1- High Weight Gain-Fast Weight Lost (HG-FL). $^2P \leq 0.01$. $^3P \leq 0.10$. $^4P \leq 0.05$. HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum; SES, socioeconomic status.
Weight and lifestyle behaviors during pregnancy and the postpartum of women for each trajectory are summarized in Table 3. The proportion of women with excessive gestational weight at the second and third trimesters of pregnancy was 1.6% and 26.5%, respectively. These values differed by trajectory, showing that women in trajectories characterized by obesity before pregnancy had the highest proportion of excessive gestational weight gain in at least one of the two moments. On the other hand, the proportion of women with insufficient gestational weight gain was the highest in the HG-FL trajectory. Women in the LG-SL trajectory were those with the highest proportion of adequate gestational weight gain in both moments of pregnancy.
Table 3  
Weight and lifestyle behaviors during pregnancy and the postpartum of women for each trajectory

| Trajectory | Time | Weight (kg) | Adequate GWG<sup>1</sup> | Excessive GWG<sup>1</sup> | Sedentary behavior<sup>2</sup> | No BF | BF | Intensity of BF (Times/d) |
|------------|------|-------------|--------------------------|--------------------------|-----------------------------|-------|----|--------------------------|
| HG-FL      | 2T   | 48.8 ± 3.6  | 4 (4.6%)                 | 1 (1.2%)                 | 58 (66.7%)                  |       |    |                          |
|            | 3T   | 54.7 ± 3.1  | 28 (40.0%)               | 4 (5.7%)                 | 38 (54.3%)                  |       |    |                          |
|            | 1 mo | 49.6 ± 3.3  |                          |                          | 53 (75.7%)                  | 4 (6.5%) | 58 (93.6%) | 8 (3)<sup>3</sup> |
|            | 6 mo | 47.4 ± 3.5  |                          |                          | 37 (67.3%)                  | 17 (33.3%) | 34 (66.7%) | 6 (5)<sup>3</sup> |
|            | 12 mo| 46.7 ± 3.7  |                          |                          | 53 (75.7%)                  | 4 (6.5%) | 58 (93.6%) | 8 (3)<sup>3</sup> |
| MG-ML      | 2T   | 56.2 ± 2.9  | 19 (9.7%)                | 2 (1.0%)                 | 140 (71.8%)                 |       |    |                          |
|            | 3T   | 62.0 ± 3.1  | 80 (48.8%)               | 16 (9.8%)                | 101 (60.5%)                 |       |    |                          |
|            | 1 mo | 57.0 ± 2.7  |                          |                          | 109 (74.7%)                 | 9 (6.4%) | 131 (93.6%) | 8 (4)<sup>3</sup> |
|            | 6 mo | 55.2 ± 3.4  |                          |                          | 82 (73.2%)                  | 35 (30.7%) | 79 (69.3%) | 8 (3)<sup>3</sup> |
|            | 12 mo| 54.6 ± 3.3  |                          |                          | 53 (75.7%)                  | 4 (6.5%) | 58 (93.6%) | 8 (4)<sup>3</sup> |
| LG-SL      | 2T   | 62.8 ± 3.6  | 54 (22.9%)               | 0 (0%)                   | 158 (66.9%)                 |       |    |                          |
|            | 3T   | 68.9 ± 3.2  | 112 (54.9%)              | 46 (22.6%)               | 126 (60.9%)                 |       |    |                          |
|            | 1 mo | 63.6 ± 3.2  |                          |                          | 137 (75.3%)                 | 14 (8.1%) | 158 (91.9%) | 8 (4)<sup>3</sup> |
|            | 6 mo | 63.0 ± 3.1  |                          |                          | 112 (75.2%)                 | 50 (38.5%) | 80 (61.5%) | 6 (4)<sup>3</sup> |

<sup>1</sup>Following IOM’s (2009) Recommendations of Gestational Weight Gain (GWG).  
<sup>2</sup>Defined as ≥ 120 minutes per day watching TV or reading books.  
<sup>3</sup>Median (interquartile range). GWG, gestational weight gain; No-BF, not breastfeeding; BF, breastfeeding; HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum; 2T, second trimester; 3T, third trimester; 1 mo, one month postpartum; 6 mo, six months postpartum; 12 mo, 12 months postpartum
| Trajectory | Time  | Weight (kg) | Adequate GWG<sup>1</sup> | Excessive GWG<sup>1</sup> | Sedentary behavior<sup>2</sup> | No BF | BF | Intensity of BF (Times/d) |
|------------|-------|-------------|----------------------|----------------------|----------------------|-------|----|---------------------|
|            | 12 mo | 62.5 ± 3.6  |                      |                      |                      |       |    |                     |
| HG-MG      | 2T    | 70.7 ± 3.3  | 66 (39.1%)           | 5 (3.0%)             | 129 (76.3%)          |       |    |                     |
|            | 3T    | 76.8 ± 3.4  | 62 (44.3%)           | 57 (40.7%)           | 80 (56.7%)           |       |    |                     |
|            | 1 mo  | 71.4 ± 3.1  |                      |                      | 99 (77.9%)           | 6 (5.0%) | 113 (94.7%) | 8 (4)<sup>3</sup> |
|            | 6 mo  | 71.0 ± 3.4  |                      |                      | 95 (84.8%)           | 29 (28.7%) | 72 (71.3%) | 7 (4)<sup>3</sup> |
|            | 12 mo | 70.8 ± 4.2  |                      |                      |                      |       |    |                     |
| HG-HG      | 2T    | 79.2 ± 4.4  | 42 (43.8%)           | 4 (4.2%)             | 61 (63.5%)           |       |    |                     |
|            | 3T    | 85.4 ± 3.6  | 28 (34.2%)           | 42 (51.2%)           | 51 (60.7%)           |       |    |                     |
|            | 1 mo  | 79.9 ± 3.8  |                      |                      | 45 (70.3%)           | 8 (13.6%) | 51 (86.4%) | 8 (4)<sup>3</sup> |
|            | 6 mo  | 80.7 ± 4.5  |                      |                      | 46 (79.3%)           | 15 (27.8%) | 39 (72.2%) | 6 (4)<sup>3</sup> |
|            | 12 mo | 80.1 ± 4.5  |                      |                      |                      |       |    |                     |
| MG-SG      | 2T    | 90.9 ± 5.6  | 18 (50.0%)           | 1 (2.8%)             | 28 (77.8%)           |       |    |                     |
|            | 3T    | 96.7 ± 4.7  | 10 (31.3%)           | 18 (56.5%)           | 21 (65.6%)           |       |    |                     |
|            | 1 mo  | 91.5 ± 4.9  |                      |                      | 18 (78.3%)           | 2 (11.1%) | 16 (88.9%) | 8 (3)<sup>3</sup> |
|            | 6 mo  | 91.3 ± 5.9  |                      |                      | 15 (68.2%)           | 6 (31.6%) | 13 (68.4%) | 6 (5)<sup>3</sup> |

<sup>1</sup>Following IOM's (2009) Recommendations of Gestational Weight Gain (GWG). <sup>2</sup>Defined as ≥ 120 minutes per day watching TV or reading books. <sup>3</sup>Median (interquartile range). GWG, gestational weight gain; No-BF, not breastfeeding; BF, breastfeeding; HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum; 2T, second trimester; 3T, third trimester; 1 mo, one month postpartum; 6 mo, six months postpartum; 12 mo, 12 months postpartum
| Trajectory | Time (kg) | Adequate GWG¹ | Excessive GWG¹ | Sedentary behavior² | No BF | BF | Intensity of BF (Times/d) |
|------------|-----------|---------------|----------------|---------------------|-------|----|-------------------------|
| 12 mo      | 91.4 ± 7.3|               |                |                     |       |    |                         |

¹Following IOM's (2009) Recommendations of Gestational Weight Gain (GWG). ²Defined as ≥ 120 minutes per day watching TV or reading books. ³Median (interquartile range). GWG, gestational weight gain; No-BF, not breastfeeding; BF, breastfeeding; HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum; 2T, second trimester; 3T, third trimester, 1 mo, one month postpartum; 6 mo, six months postpartum; 12 mo, 12 months postpartum

Regarding sedentary behavior and breastfeeding practices, the HG-MG trajectory showed a higher proportion of women who were sedentary at one and six months postpartum. One third of women breastfed exclusively at one month postpartum and 1.92% continued at six months postpartum. Most of the women (~ 60%) reported no exclusive breastfeeding at both study visits. The median intensity of breastfeeding was eight times per day (interquartile range (IQR) = 3) in the first month and seven times/day (IQR = 5) at six months. At one month postpartum, we observed that women in HG-HG and MG-SG trajectory were those with a higher proportion of not breastfeeding. However, this finding was not observed at six months postpartum, where a higher frequency of not breastfeeding was observed in women belonging to LG-SL trajectory.

Discussion

We identified six types of weight change trajectories running from the second trimester of pregnancy up one year after delivery among Mexican adult women. All groups increased weight during pregnancy, followed by a substantial loss at one month postpartum; however, the weight change and its timing varied according to the six trajectories. The main difference in the trajectories was the change seen after one month postpartum. Trajectories of weight change were characterized mainly by pre-pregnancy BMI and maternal age. Furthermore, having more than two children previous to current pregnancy, category of SES, less than ten years of schooling, having a partner, and working outside the home were also related to the type of trajectory.

Sixty percent of the women returned to their second-trimester weight and continued to lose weight during the first postpartum year. Leonard et al. observed a similar pattern in ~ 60% of their study population among young and adult women from the US [21]. The latter is inconsistent with the findings from another US cohort, Project Viva, where they found that 84.6% of women sustained a weight loss upon 12 months [22]. On the contrary, approximately 30% of the women from our study did not return to the weight at the second trimester and even gained weight by the first year postpartum. This percentage of women is higher than
reported in other studies. In Project Viva, which used the same statistical model to identify trajectories as in the present analysis, all the women continued to lose weight at a different rate during the first postpartum year. These differences may be due to the characteristics of the population included in the trajectories of Project Viva, in which women were older and with higher years of schooling and socioeconomic status, compared with women's characteristics of the present study. Also, other studies have reported weight retention and increased weight among 11% of Danish women and 5.6% of Norwegian women at six months postpartum [23, 24]. Our findings regarding weight retention and increase weight before six months of postpartum may contribute to the burden of obesity in Mexican women [25]. The studies mentioned above observed a weight gain in the late postpartum (> 12 months) even when they returned to their pre-pregnancy weight.

Most women with pre-pregnancy obesity (97%) from this study started to gain weight around six months postpartum. The latter is consistent with the evidence, where overweight and obesity are risk factors to postpartum weight retention and body mass increase later in life [6]. However, our findings showed that even among the same pre-pregnancy BMI, they might followed different weight change trajectories that may be it relating to sociodemographic factors. It is well known that older women may have a higher BMI and chance of beginning their pregnancy with overweight or obesity. This association is not clear since parity may have a role in it.²⁶ We observed that multiparity (> 2 children) might influence weight gain upon postpartum. Nevertheless, this finding is not consistent with other studies [26]. In addition, women with social support during postpartum are likely to have healthier lifestyles that contribute positively to their postpartum weight [27]. Our findings did not support this association, where women with a partner were more likely to be in trajectories followed by an increased weight after six months postpartum, suggesting that other factors may be related to postpartum weight change along with lifestyle behavior.

We want to highlight the characteristics of women more likely to be in trajectory LG-SL. Although these women were significantly older and with higher pre-pregnancy BMI than women from the reference HG-HL trajectory, they also lost weight after six months postpartum. Nevertheless, this trajectory had a higher proportion of women with more than ten years of schooling, higher socioeconomic status, and adequate gestational weight gain. In this way, continuing to lose weight during postpartum in these women may be explained by these characteristics related to healthful behaviors [28, 29].

The role of gestational weight gain on postpartum weight change has been previously established in other countries [6]. Our findings in Mexico are consistent with these results. During the first postpartum year, trajectories with continuous weight loss were those with a lower proportion of excessive gestational weight gain. As mentioned earlier, this may contribute for women with overweight before pregnancy to be in LG-SL trajectory.

Postpartum behaviors impact weight change after delivery [30]. In line with our findings, sedentary behavior during postpartum life has been associated with postpartum weight retention, regardless of pre-pregnancy BMI [31, 32]. In contrast, high physical activity influences weight loss or negative postpartum weight retention. We did not observe a relationship with physical activity in our sample since this behavior was similar among trajectories and with lower activity intensity (data not shown). Pregnant and postpartum
women have reported lower or null physical activity in these states due to socio-cultural beliefs, physical discomfort, limited access, or lack of time [33, 34]. Breastfeeding practices are another postpartum behavior related to weight change [30–35]. Our findings showed that women in the trajectories with weight gain and slow weight loss after six months postpartum were those with a higher proportion of cessation of breastfeeding at one and six months postpartum, respectively. These breastfeeding practices may be due to poor technique and sociodemographic factors such as pre-pregnancy obesity, return to work, and lack of support to maintain breastfeeding [36–39].

We noted that the present study is the beginning of a novel approach to identify weight change trajectories in women of reproductive age. However, our approach does not allow us to determine causal inferences or assess the intermediate role of postpartum behaviors. Nevertheless, the identification and characterization of these six trajectories contribute to 1) understanding the heterogeneity of the weight change during these periods, 2) identifying a more sensible period, and 3) distinguishing women with a higher risk of sustained weight gain.

Beyond the weight change after giving birth, it is essential to evaluate the consequences of this change on health. In another type of analysis from this cohort, Soria et al. found that women with postpartum weight retention and weight gain at 12 months had a higher BMI, weight circumference, and insulin resistance at six years postpartum than women who returned to their pre-pregnancy weight [40]. The relation between fat mass accumulation during pregnancy and postpartum with cardiovascular risk factors in later years was also reported in women from Project Viva and Danish National Birth Cohort [23, 24]. Postpartum maternal weight change trajectories are also associated with children with higher weight for height and energy intake among the Mexican population [41].

Our study has some strengths and limitations. One of the strengths of this study is that we measured and analyzed weight prospectively from pregnancy to one year postpartum at different points, allowing us to study the timing of weight change; contrary to the current literature on the topic, which cannot identify the timing of weight change [6]. However, one limitation of our study was that the research team could not measure pre-pregnancy weight, influencing the trajectories starting in the second trimester of pregnancy. We used predicted weight to address the bias associated with weight underreporting and misclassification to overcome this limitation. Although we included women without postpartum data to run a group-based trajectory model, it may be possible that we were missing other factors that characterize each trajectory. However, we only observed differences in pre-pregnancy BMI between women with complete and incomplete data. Our findings do not apply for women with a lower duration of gestation (< 37 weeks) or adverse perinatal outcomes.

Conclusions

Interventions to prevent women's obesity during pregnancy and postpartum should be addressed as a continuous process. Efforts should be directed to establish timely and effective pre-conception and inter-pregnancy interventions in women with overweight or obesity to influence the cycle of obesity and chronic diseases. Interventions and strategies also need to consider women's characteristics that influence weight
retention and weight gain to support and promote healthy lifestyle behaviors. Other studies are needed to validate the reproducibility of these trajectories and explore how these trajectories are related to the risk of diseases in later stages.

**List Of Abbreviations**

HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum

**Declarations**

**Ethics approval and consent to participate**

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board at the Instituto Nacional de Salud Pública (#560CI-020). Women provided written informed consent

**Consent for publication**

Not applicable

**Availability of data and materials**

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

**Competing interests**

The authors declare no conflict of interest.

**Funding**

The PROGRESS cohort obtained financial support from the National Institute of Environmental Health Sciences grants R01 ES014930, R01 ES013744, R00 ES023474 and R01 ES021357.

**Author’s contributions**

The authors’ contributions were as follows — CMM and BTV: conceptualized and designed the study; MMTR, AC, ALD, EC, MMN, ROW, and AAB: designed research, collected data, and participated in the critical interpretation of the data; CMM and BTV: analyzed data and performed statistical analysis; CMM, MMTR, BTV, and SHC: wrote the manuscript; ALD: critically reviewed the manuscript; BT: had primary responsibility for the final content. All authors read and approved the final manuscript.
Acknowledgements

We acknowledge recruitment and administrative support to Adriana Mercado-García and also to the American British Cowdray Medical Center for her support, providing the research facilities. We thank Allan Just for his contribution to predicting pre-pregnancy weight. We also thank Ana Isabella Ley for assistance in the manuscript editing process.

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**Figures**

![Figure 1](image)

**Figure 1**

Trajectories of weight change (kg) from the second trimester of pregnancy to one year postpartum

The trajectories were out of phase-based to the average weight of the second trimester of pregnancy, starting at 0 kg (indicating without change). The key denotes the type of trajectories named HG-FL (solid), MG-ML (short dash-dot-dot), LG-SL (long dash-short dash-short dash), HG-MG (dash), HG-HG (very short dash), and MG-SG (long dash). HG-FL, high weight gain during pregnancy and fast weight loss postpartum; HG-HG, high weight gain during pregnancy and high gain postpartum; HG-MG, high weight gain during pregnancy and moderate gain postpartum; LG-SL, lower gain during pregnancy and moderate loss postpartum; MG-SG, moderate weight gain during pregnancy and slow gain postpartum; MG-ML, moderate weight gain during pregnancy and moderate loss postpartum.