Non-Linear Relationships Between Maternal Pre-Pregnancy Body Mass Index, Gestational Weight Gain and Duration of Breastfeeding

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Abstract

Background: Considering the potential inappropriateness of the 2009 Institute-of-Medicine criteria to Chinese women, we investigated the associations between pre-pregnancy body-mass-index (BMI), gestational-weight-gain (GWG) and breastfeeding-duration among Chinese women.

Methods: This birth-cohort study included 225 mother-child pairs in Shanghai from 2010 to 2012. Mothers were interviewed during mid-to-late pregnancy and at 24-36 months postpartum. Information on pre-pregnancy BMI/GWG and breastfeeding-duration was collected during pregnancy and at 24-36 months postpartum, respectively. Using a data-driven approach based on spline-smoothing-fitting of the data, two-piecewise linear regression models were used to assess the relations between pre-pregnancy BMI, GWG and breastfeeding-duration.

Results: Mothers being younger, longer daily working hours, and less time living with children per week were associated with shorter duration ($P<0.05$). The "inverted-U"-shaped and "flat-then-declining"-shaped associations between pre-pregnancy BMI, GWG and breastfeeding-duration were observed, respectively. Adjusting for related confounders, the increases in pre-pregnancy BMI below and above 22.5 kg/m$^2$ were associated with an increase ($P=0.044$) and a marginal decrease ($P=0.077$) in breastfeeding-duration, respectively. One-kilogram increase in GWG was associated with 0.4-month decrease (95% CI: -0.7, -0.1) in breastfeeding-duration when GWG $\geq$ 17.5 kilograms, however, with nonsignificant changes when GWG < 17.5 kilograms.

Conclusion: Appropriate pre-pregnancy BMI (around 22.5 kg/m$^2$) and GWG (< 17.5 kilograms) were favorable to sustained breastfeeding.

Keynotes

- Appropriate pre-pregnancy BMI (around 22.5 kg/m$^2$) and gestational-weight-gain (< 17.5 kilograms) were favorable to sustained breastfeeding.
- The "inverted-U"-shaped association between pre-pregnancy BMI and maternal breastfeeding-duration was observed.
- The "flat-then-declining"-shaped association between gestational-weight-gain and breastfeeding-duration was observed.

Background

Breastfeeding is considered the best way to feed infants (1). Longer duration of breastfeeding has significant health benefits for infants and mothers (1–5). Although breastfeeding education has been carried out worldwide, the rate of exclusive breastfeeding within the first 6 months of life has experienced a quick decline in recent two decades (6–9). Many mothers throughout the world still never breastfeed, or
breastfeed for less time than recommended (2). Therefore, it's important to identify factors influencing the duration of breastfeeding.

Maternal biomedical factors may potentially influence breastfeeding practice (2, 10, 11). Weight gain during pregnancy may be associated with changes in glucose and lipid metabolisms and may have important implications for pregnant women and their offspring in their later lives (12–14). Factors influencing maternal pre-pregnancy body mass index (BMI) such as dietary habits may also affect the fatty acid composition of breast-milk (15, 16). Previous studies found that lower high-density lipoprotein cholesterol levels (17), and higher levels of fat and energy contents in human milk were associated with longer lactation time (18). Thus, we hypothesized that gestational weight gain (GWG) and pre-pregnancy BMI may affect breastfeeding duration.

Previous studies have reported that pre-pregnancy overweight/obesity or excessive gestational weight gain (GWG) defined based on the 2009 Institute of Medicine (IOM) criteria has adverse impacts on maintaining breastfeeding (10, 19–21). However, because pre-pregnancy normal and underweight were often combined as pre-pregnancy non-overweight/obesity in previous studies (22), the effects of pre-pregnancy underweight were less studied, and the independent contribution of GWG on the breastfeeding duration also needs to be clarified (19). In addition, potential confounding by maternal factors may exist in previous studies such as employment status and workloads, life habits, stress, as well as delivery mode, each of which may affect breastfeeding (2, 10–12). However, few studies have accounted for all these risk factors in the same population. Another important issue is the potential inappropriateness of the 2009 IOM criteria to Chinese women. Chinese women usually have lower pre-pregnancy BMI and more weight gains during pregnancy than western women (23). Based on the 2009 IOM recommendation, more than fifty percent of women of childbearing age living in North China exhibited excessive GWG (24, 25). The studies on the appropriate GWG and pre-pregnancy BMI in the Asian population are very limited and the related conclusions are controversial (26, 27), and the potentially inappropriate pre-pregnancy BMI and GWG among Chinese women and their impacts on women and the offspring have been of great concern for the Chinese public health system.

Therefore, we conducted a prospective birth-cohort study to explore the independent impacts of pre-pregnancy BMI and GWG on breastfeeding duration in China.

**Methods**

**Study design and recruitment.** We conducted a longitudinal birth-cohort study from mid-to-late pregnancy through the children’s first two years of life. Mother-child pairs were recruited from antenatal clinics of 2 hospitals in Shanghai from February to September 2010. Study data were collected via in-person interviews with the pregnant women during mid-to-late gestation (at 28-36 weeks of gestation) and with the mothers at 24-36 months postpartum, and via medical history records at the 12th week of gestation (pre-pregnancy height and weight information) and at delivery (birth information). Singleton pregnant women who had no mental disorders and who were without severe complications of pregnancy were
considered eligible. The mother-infant pairs were also excluded if the infant had a clinical diagnosis of perinatal asphyxia (Apgar scores at 5 minutes were 7 or lower). A total of 398 pregnant women who visited the antenatal clinics were invited to participate, and 173 mother-child pairs were out of contact or declined to participate in the follow-up interview. Therefore, the study sample included 225 mother-child pairs. There were no significant differences in maternal age, ethnicity, education or economic status between the mother-child pairs who were followed up and those who were not(28).

The study was approved by the Medical Research Ethics Committee of Shanghai Xinhua Hospital, Shanghai Jiao Tong University School of Medicine, and written informed consent was obtained from all study participants.

**Exposures.** The pre-pregnancy BMI and GWG were the main exposure variables. Pre-pregnancy weight was self-reported, and maternal height and weight were also measured at the first prenatal visit at the 12th week of gestation. The height was measured twice by the same investigator to the nearest 0.1 cm, using medical height meter (SECA 799, Hangzhou, China), with the subjects standing without shoes. The weight was also measured twice by the same investigator to the nearest 0.1 kg, using a medical calibrated weighing scale (SECA 799, Hangzhou, China), with subjects only wear underclothing. If readings differed by more than 1cm and 0.2 kg for the height and weight, respectively, a third measurement was taken and the average of all three readings were used. If the difference between self-reported and measured weight was over 2kg, the woman would be inquired again to assure that her self-reported pre-pregnancy weight was correct. Pre-pregnancy BMI was calculated based on pre-pregnancy weight and maternal height. Pre-delivery weight was obtained from medical record at delivery. GWG was calculated as pre-delivery weight minus pre-pregnancy weight.

**Outcome.** The primary outcome was the duration of breastfeeding (the number of months breastfeeding lasted). An in-person interview was performed by trained researchers at 24-36 months postpartum, and women were asked questions about their infants’ feeding type (formula-feeding, breast-milk-feeding or mixed feeding) and the duration of breastfeeding (“did you ever breastfeed your child?", "at what age of the infant did you stop breastfeeding?", "did you ever introduce another kind of milk than breast-milk to your child?", "at what age of the infant did you introduce another kind of milk than breast-milk to your child?"). In this study, breastfeeding duration referred to the duration of any breastfeeding, that is to say, the number of months the infant received any breast-milk, irrespective of the concomitant introduction of other milk and foods. The breastfeeding duration among mothers who never breastfed their children was defined as "zero" month.

**Covariates.** Information on covariates was collected from the interviews during mid-to-late pregnancy and at 24-36 months postpartum, and from medical record at delivery. Because of possible changes between the pregnancy and postpartum periods, information on marital status, family monthly income, housing area per capita, maternal occupation, employment, workloads (daily working hours), smoking and alcohol consumption, and stress was repeatedly collected during pregnancy and at 24-36 months postpartum. Other information collected prenatally included maternal age at enrollment, ethnicity and maternal
education. Information collected at birth included children's gender, birth weight, length, head circumference, parity, gestational weeks, and delivery mode. Whether or not the women had caesarean-section (C-section) delivery without medical indications was based on the medical records at delivery, and would be confirmed by the mother herself at 24-36 months postpartum. Information collected at 24-36 months postpartum also included days the mother living with her child per week, family interpersonal relationship, and family atmosphere.

Maternal emotional stress levels were assessed using Symptom Checklist-90-Revised (SCL-90-R) during mid-to-late pregnancy and toddlerhood. The SCL-90-R is widely used, valid and reliable in assessing maternal psychological symptoms (29). The global severity index (GSI) is calculated by dividing the total score of SCL-90-R by 90. Higher GSI scores indicated higher emotional distress levels (30).

**Statistical analyses.** We first analyzed maternal and infant demographic characteristics and their unadjusted association with breastfeeding duration. Chi-square test was used to compare the difference in feeding types among mothers with different delivery modes.

Because the applicability of GWG grouping based on the 2009 IOM recommendation may be not appropriate for Chinese pregnant women (30), we did not define excessive or inadequate GWG according to current grouping criteria recommended by the IOM, but used GWG and pre-pregnancy BMI as continuous variables. We first applied smoothing splines to visually inspect the shape of the associations of pre-pregnancy BMI and GWG with breastfeeding duration, then according to the shapes of the associations (non-linear associations were observed), two-piece-wise linear regression models were fitted to describe the effects of maternal pre-pregnancy BMI and GWG on the breastfeeding duration with the package ‘segmented’ in R software (http://www.R-project.org). The turning point of BMI and GWG where the relationship between BMI, GWG and breastfeeding duration started to change and became eminent was determined using trial method, which was to move the trial turning point along the pre-defined interval and picked up the one which gave maximum model likelihood. For all models using breastfeeding duration as the outcome, confounders were selected based on the observed bivariate associations with the outcome (breastfeeding duration) or the exposures (pre-pregnancy BMI or GWG), or from the literature. Because only five mothers were from ethnic minorities, and all mothers were married and didn't smoke, therefore, ethnicity, marital status and smoking were not controlled in the models.

**Results**

Among the participating mother-child pairs, the mean age of the mothers at enrollment was 29.0 years old. A total of 6.7% and 12.4% of mothers had a junior-middle-school or lower education, and postgraduate-level education, respectively. None of the women smoked during pregnancy and postpartum, and 24.5% and 37.8% of mothers didn't work and worked "full-time" during the whole pregnancy, respectively. The mean gestational week was 39.4 weeks. The ratio of boys to girls was 44:56. The percentages of vaginal delivery, C-section with and without indications were 33.8%, 32.0% and 34.2%, respectively (Table I). Five mothers (2.2%) had preterm births, one child (0.4%) had the birth-weight
less than 2.5 kg (2.3 kg), and 18 children (8.0%) had birth-weights over 4.0 kg. The percentages of the mothers working "full-time" before pregnancy and after maternity leave were 95.9% and 88.4%, respectively, and the intraclass correlation coefficient between the workloads before pregnancy and after maternity leave was 0.4 ($P<0.001$). A total of 14.7% of mothers worked overtime frequently during the toddlerhood, and only 9.8% of mothers were full-time mothers. Only 74.4% of mothers lived with their children every day. The prenatal and postnatal maternal emotional stress levels were both within the normal ranges (29), and the intraclass correlation efficient between prenatal and postnatal GSI was 0.3 ($P=0.014$).

The pre-pregnancy BMI was (22.1 ± 2.9) kg/m$^2$, and the GWG was (15.0 ± 4.7) kg. Compared with the 2009 IOM criteria (30), the prevalence of pre-pregnancy obesity/overweight (BMI ≥ 25 kg/m$^2$) was 16.9%, and the mean of GWG among these women (13.9 kg) was above the 2009 IOM recommendation (< 11.5 kg). Bivariate analyses showed that mothers with lower social-economic-status had higher pre-pregnancy BMI. Women who had higher educational levels, higher pre-pregnancy BMI, and who worked continuously or intermittently (compared with those who did not work) during pregnancy had lower GWG ($P<0.05$). Using multivariate regressions, adjusting for potential confounders, we also observed that lower family monthly income was associated with higher pre-pregnancy BMI ($P<0.05$). Mothers who continuously or intermittently worked (compared with those who did not work) during pregnancy, and who had higher pre-pregnancy BMI had lower GWG ($P<0.05$).

The mean duration of breastfeeding was 7.4 months. In total, 91.8% of mothers initiated breastfeeding. Compared with the WHO recommendations that exclusive breastfeeding should be until 6 months postpartum (31), only 38.1% of mothers who initiated breastfeeding had exclusive breastfeeding for 6 months postpartum, and the 6-month "any breastfeeding" rate was 66.8%. Compared with mothers working more than 8 hours per day, mothers working less than 5 hours per day had longer breastfeeding duration ($P<0.05$). Younger mothers and mothers living less days per week with children were associated with shorter breastfeeding durations (all $P$ values < 0.05) (Table II). Although mothers who had C-section deliveries without medical indications had non-significantly shorter breastfeeding duration compared with their counterparts who had vaginal deliveries or C-section deliveries with medical indications, their "any breastfeeding" rate was significantly lower and their "formula-feeding" rate was significantly higher ($P<0.05$).

Without adjustment for potential confounders, non-linear associations were observed between pre-pregnancy BMI, GWG and breastfeeding duration, including the "inverted-U"-shaped association for pre-pregnancy BMI and breastfeeding duration, and "at-then-declining"-shaped association for GWG and breastfeeding duration. Pre-pregnancy BMI at about 22.5 kg/m$^2$ appeared to be the inflection point. Breastfeeding duration didn't change significantly with GWG when GWG < 17.5 kg. However, when GWG reached 17.5 kg or higher, breastfeeding duration had an inverse association with GWG. Adjusting for potential confounders, the shapes of the associations between pre-pregnancy BMI, GWG and breastfeeding duration were similar as those from the unadjusted models (Fig. 1). In two piece-wise linear regression models, after adjusting for maternal age, education, family income, gestational age, mode of
delivery, maternal stress, workloads after maternity leave, days mothers living with children per week, infant sex, birthweight and parity, we observed that when pre-pregnancy BMI was below 22.5 kg/m², the increase in pre-pregnancy BMI was associated with increased breastfeeding duration (P = 0.044, Table 1). However, when pre-pregnancy BMI was above 22.5 kg/m², the increase in pre-pregnancy BMI was associated with a marginally significant decrease in breastfeeding duration (P = 0.077, Table 1, Fig. 1).

After adjusting for maternal age, education, family income, pre-pregnancy BMI, gestational age, mode of delivery, maternal stress, workloads after maternity leave, days mothers living with children per week, infant sex, birthweight and parity (Table 1) in piece-wise linear regression models, breastfeeding duration didn’t change significantly with increasing GWG if GWG was < 17.5 kg. However, when GWG was 17.5 kg or higher, 1 kg increase in GWG was significantly associated with a 0.4-month (95%CI: -0.7, -0.1, P = 0.024) decrease in breastfeeding duration. The P-values for the two piecewise linear models against the single linear regression models were 0.020 and 0.026 for the models using pre-pregnancy BMI and GWG as the main predictors, respectively (Fig. 1, Table 1) (32).

Discussion

We found non-linear associations between pre-pregnancy BMI, GWG and breastfeeding duration.

Compared with literature reports, the prevalence of having initiated breastfeeding in our study (91.8%) was slightly lower than the reported rates in rural counties in Chinese central and western provinces (33), but significantly higher than the reported rates in the United states in 2007 (1), and slightly lower than the reported rate in Norwegians between 1999 and 2008 (10). The mean breastfeeding duration in our study (7.4 months) was similar as the duration reported in a previous study (2). The rate of 6-month exclusive breastfeeding (38.1%) was similar as those reported in developing countries (36–39%) (4, 34), but significantly higher than the reported rate in Canada (35). In addition, the rate of 6-month "any breastfeeding" (66.8%) was higher than the rate reported in the U.S in 2010 (43%) (1). Therefore, about two thirds of our study women breastfed their infants during the first 6 months postpartum, but only about one third infants were exclusively breastfed.

Our findings are consistent with previous studies showing that older mothers (2, 34), and mothers working less time or living more time with their children after maternity leave had longer duration of breastfeeding (11, 36, 37). Shanghai is an international metropolitan city in China, and Shanghai women have been considered as the example of "gender equality". Women in Shanghai are usually employed (95.9% before pregnancy and 88.4% during their children's toddlerhood based on our study). Because of heavy workloads and insufficient resources to bring up infants alone, some of Shanghai women (25.6% in our study) leave their children living with their parents or parents-in-law some days per week. Excessive workloads and insufficient maternal-infant contact may cause early termination of breastfeeding (38). It's interesting to note that, consistent with a previous study (39), we found a lower "any breastfeeding" rate among women with C-section without medical indications than those women with a vaginal delivery or C-section with indications. Our findings confirmed the results showed in previous studies that the rates of C-
section rose rapidly in China (39, 40), and reducing C-sections without medical indications may be helpful for promoting their breastfeeding.

Our study found that very low or high pre-pregnancy BMI was unfavorable for women to sustain breastfeeding. In this birth-cohort study, consistent with most of previous studies (10, 19–21), we observed that the duration of breastfeeding became shorter with an increase in pre-pregnancy BMI when BMI > 22.5 kg/m². This may be due to difficulties in maintaining the gesture to place the baby in breastfeeding position, limited production of prolactin, delayed lactogenesis stage II (10, 20, 41), and other psychosocial factors (10) in pre-pregnancy overweight/obese women. Inconsistent findings have been reported in previous studies on the impact of pre-pregnancy underweight on the duration of breastfeeding (10, 20, 22, 42, 43). Some studies found an adverse impact (10, 42), which was consistent with our findings, but other studies found no association (20, 43). The difference between the previous studies and ours may be because that the populations were of different races and different adjustment for confounders (21). Our study suggested that, in addition to pre-pregnancy overweight and obesity, health care professionals should pay attention to pre-pregnancy underweight as a risk factor for short lactation duration.

Our study showed that when GWG was 17.5 kg or higher, GWG was inversely associated with breastfeeding duration. GWG of 17.5 kg was at the 73th percentile in this study and above most of the 2009 IOM recommendations for various pre-pregnancy BMI groups (recommended GWG for pre-pregnancy underweight, normal weight and overweight/obese women were 12.5–18 kg, 11.5–16 kg, and 5–11.5 kg, respectively) (30). Therefore, excessive GWG appears to be common in these Shanghai pregnant women (27% of the study women), and our study showed that a higher GWG was significantly associated with a lower rate of working during pregnancy (maybe due to one-child policy in China, women in Shanghai worked less during pregnancy to ensure a safe pregnancy), and with relatively low pre-pregnancy BMI (in our study women, only 1.3% of mothers had pre-pregnancy BMI ≥ 30 kg/m²; however, recent researches showed that 21.4% of American mothers had pre-pregnancy BMI ≥ 30 kg/m²) (44). Although our study didn’t group women based on the 2009 IOM criteria, our finding is consistent with previous studies showing that excessive GWG was associated with a failure to sustain breastfeeding (19, 42). However, our study didn’t find significant association between inadequate GWG with early termination of breastfeeding as reported in a previous study (42). The inconsistence may be due to the differences in the adjustment for confounders (maternal stress, workloads after maternity leave, days mothers living with the infant per week, and whether C-section without medical indications or not, were not controlled in that study) and in the study populations (only women from low-income families were recruited in that study) (42).

Our study also had some limitations. First, the modest sample size in our study may result in insufficient statistic power in detecting small differences. Second, we didn’t collect information on infant’s sucking behaviors. Some women may use pumps or hands to express breast-milk which may have different impacts on breast-milk production compared with infant’s sucking behaviors. Therefore, we cannot rule out the potential confounding effects of breast-milk expression on breastfeeding duration (15). Third, we
didn’t measure pre-pregnancy waist circumference which was shown to be a confounder in the association between GWG and breastfeeding behavior (45). Fourth, all the women in our study were from Shanghai, caution should be taken when generalizing these results to other populations. Finally, we didn’t collect breastfeeding information at multiple time points after delivery, but asked the women to recall breastfeeding information about 24 months after they stopped breastfeeding. However, according to a previous study, breastfeeding duration could be recalled quite accurately even 20 years after delivery (46).

**Conclusion**

Our study showed that too thin or too fat before pregnancy and GWG over 17.5 kg are unfavorable factors influencing the duration of breastfeeding. Considering the current exclusive-breastfeeding rate is still low (2, 47, 48), appropriate pre-pregnancy BMI (around 22.5 kg/m²) and GWG (< 17.5 kilograms) are suggested for sustained breastfeeding. Structured programs such as pre-pregnancy/ antenatal education and comprehensive lactation guidance are suggested to increase the exclusive breastfeeding rate, and to promote sustained breastfeeding (49), particularly among women who have an inappropriate pre-pregnancy BMI and excessive GWG.

**Abbreviations**

BMI - body-mass-index; GWG - gestational-weight-gain; IOM - Institute of Medicine; C-section - caesarean-section; SCL-90-R - Symptom Checklist-90-Revised; GSI - global severity index

**Declarations**

**Ethics approval and consent to participate**

The study was approved by the Medical Research Ethics Committee of Shanghai Xinhua Hospital, Shanghai Jiao Tong University School of Medicine. Written informed consent was obtained from all study participants.

**Consent for publication**

Not applicable.

**Availability of data and materials**

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

**Competing interests**

The authors declare that they have no competing interests.
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Authors' contributions

Prof. Xu J wrote the first draft of this manuscript, including doing data analyses and making figures. Prof. Xu J is responsible for the study design. Zhang YJ, Lin YF, Liu ZW and Huang J performed data collection and literature search. Zhang YJ and Cao SR helped data analyses. Prof. Luo ZC helped data interpretation. All authors have read and approved the final version of the manuscript.

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Authors' information (optional)

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Tables
Table 1
Demographic characteristics of the study cohort (225 mother-child pairs) and the associations with duration of breast-feeding

| Variables | N(%) or mean ± SD or median (P25, P75) | Unadjusted association with duration of breast-feeding [β (95%CI)] | \( P^a \) |
|-----------|--------------------------------------|---------------------------------------------------------------|------|
| Maternal age (years, missing n = 0) | | | |
| < 25 | 19(8.4) | Reference | |
| ≥ 25, and < 30 | 127(56.4) | 2.1(-0.1, 4.4) | 0.062 |
| ≥ 30 | 79(35.1) | 3.2(0.9, 5.6) | 0.007 |
| Family income (RMB/month, missing n = 0) | | | |
| < 2000 | 12(5.3) | Reference | |
| 2000–5000 | 64(28.4) | 0.0(-2.9, 2.9) | 0.991 |
| 5000–10000 | 91(40.4) | 0.2(-2.7, 3.0) | 0.895 |
| >10000 | 58(25.8) | 0.5(-2.4, 3.4) | 0.735 |
| Maternal education, missing n = 0) | | | |
| Junior middle school or lower | 15(6.7) | Reference | |
| Senior middle school | 20(8.9) | -2.1(-5.2, 1.0) | 0.189 |
| University or college level | 162(72.0) | -1.4(-3.8, 1.1) | 0.283 |
| Postgraduate level | 28(12.4) | 0.1(-2.8, 3.1) | 0.930 |
| GSI during pregnancy (missing n = 0) | 1.2 ± 0.2 | -1.1(-4.0,1.8) | 0.465 |
| GSI at 24–30 months postpartum (missing n = 0) | 1.3 ± 0.3 | -1.2(-3.2,0.9) | 0.268 |
| Mode of delivery (missing n = 0) | | | |
| Vaginal | 76(33.8) | Reference | |
| C-section with indications | 72(32.0) | -0.1(-1.6, 1.5) | 0.939 |

\(^a\)ANOVA or chi-square

GSI: global severity index; C-section: caesarean-section; GWG: gestational weight gain; BMI: Body Mass Index
| Variables                                      | N(%) or mean ± SD or median (P25, P75) | Unadjusted association with duration of breast-feeding $[\beta (95\%CI)]$ | $P^a$ |
|------------------------------------------------|----------------------------------------|--------------------------------------------------------------------------|-------|
| C-section without indications                 | 77(34.2)                               | -1.1(-2.6, 0.4)                                                          | 0.165 |
| Gestational weeks (missing n = 0)             | 39.4 ± 1.2                              | 0.0(-0.5, 0.5)                                                           | 0.943 |
| GWG (kg, missing n = 10)                      | 15.0 ± 4.7                              |                                                                          |       |
| GWG < 17.5 kg                                 | 153(71.2)                               | 0.1(-0.1,0.4)                                                            | 0.222 |
| GWG ≥ 17.5 kg                                 | 62(28.8)                                | -0.4(-0.7,-0.1)                                                          | 0.019 |
| Prepregnancy-BMI (kg/m$^2$, missing n = 0)   | 22.1 ± 2.9                              |                                                                          |       |
| $\beta_1$ (BMI < 22.5)                        | 140(62.2)                               | 0.5(0.0, 0.9)                                                            | 0.041 |
| $\beta_2$ (BMI ≥ 22.5)                        | 85(37.8)                                | -0.4(-0.8,0.0)                                                           | 0.036 |
| Child sex (missing n = 0)                     |                                        |                                                                          |       |
| Boy                                           | 99(44.0)                                | Reference                                                                |       |
| Girl                                          | 126(56.0)                               | -0.4(-1.6, 0.9)                                                          | 0.549 |
| birthweight (kg, missing n = 0)               | 3.5 ± 0.4                               | 0.0 (0.0, 0.0)                                                           | 0.591 |
| Maternal characteristics postpartum           |                                        |                                                                          |       |
| Daily working hours after maternity leave (missing n = 1) | | | | |
| > 8 h/day                                      | 109(48.7)                               | Reference                                                                |       |
| 5–8 h/day                                     | 90(40.2)                                | 0.3(-1.0, 1.6)                                                           | 0.636 |
| < 5 h/day                                     | 25(11.2)                                | 3.1(1.1, 5.2)                                                            | 0.002 |
| Days living with children per week (missing n = 2) | | | | |
| 7 days/week                                   | 166(74.4)                               | Reference                                                                |       |
| ≤ 6 days/week                                 | 57(25.6)                                | -2.4(-3.8, -1.0)                                                         | <0.001|

$^a$ANOVA or chi-square

GSI: global severity index; C-section: caesarean-section; GWG: gestational weight gain; BMI: Body Mass Index
Table 2

| Adjusted effects of pre-pregnancy BMI\(^{a,b}\) | Adjusted effects of GWG\(^{a,b,c}\) |
|-----------------------------------------------|-----------------------------------|
| Model type                                    | \(\beta\) (95%CI)                 | \(P\)-values | Model type                                    | \(\beta\) (95%CI) | \(P\)-values |
| One linear regression                         | 0.0 (-0.2, 0.2)                   | 0.884        | One linear regression                        | -0.1(-0.2, 0.1)   | 0.397         |
| Piece-wise linear regression                  | \(\beta_1\) (BMI < 22.5 kg/m\(^2\)) | 0.5(0.0, 1.0) | 0.044                                        | \(\beta_1\) (GWG < 17.5 kg) | 0.1 (-0.1, 0.3) | 0.311         |
|                                              | \(\beta_2\) (BMI \(\geq\) 22.5 kg/m\(^2\)) | -0.4(-0.8,0.0) | 0.077                                        | \(\beta_2\) (GWG \(\geq\) 17.5 kg) | -0.4(-0.7, -0.1) | 0.024         |
|                                              | \(\beta_2 - \beta_1\)             | -0.9(-1.6,-0.1) | 0.028                                        | \(\beta_2 - \beta_1\) | -0.5(-1.0, 0.0) | 0.036         |
| Likelihood ratio test \(P\) value            | 0.020                             |              | Likelihood ratio test \(P\) value            | 0.026                             |              |

\(^a\) Adjusted for maternal age, education, family income, gestational age, mode of delivery, maternal stress, workloads after maternity leave, days mothers living with children per week, infant sex, birthweight and parity. \(^b\) Ethnicity was not controlled because only 5 mother-child pairs were from ethnic minorities, marital status and smoking were not controlled because no mothers were single or smoked during pregnancy or postpartum. \(^c\) Pre-pregnancy BMI was further controlled.

Figures
Figure 1

Effects of maternal pre-pregnancy BMI and gestational weight gain on breastfeeding duration. Unadjusted (A) and adjusted (B) non-linear associations between pre-pregnancy BMI and duration of breastfeeding both showed that the increases in pre-pregnancy BMI among women with BMI below 22.5 kg/m² were associated with an increase (P=0.044) in breastfeeding duration, while the increases in pre-pregnancy BMI among women with BMI above 22.5 kg/m² with a marginal decrease (P=0.077).

Unadjusted (C) and adjusted (D) non-linear associations between gestational weight gain and duration of breastfeeding both showed that the increase in GWG was associated with the decrease in breastfeeding duration when GWG ≥ 17.5 Kg, however, with no significant changes when GWG <17.5 Kg. BMI, body mass index; GWG, gestational weight gain.