# *Pregnancy after Bariatric Surgery: Obstetric and Perinatal Outcomes and the Growth and Development of Children*

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ORIGINAL CONTRIBUTIONS

# Pregnancy after Bariatric Surgery: Obstetric and Perinatal Outcomes and the Growth and Development of Children

**Cátia Millene Dell'Agnolo [1] · Caroline Cyr [2] · Francine de Montigny [3] · Maria Dalva de Barros Carvalho [4] · Sandra Marisa Pelloso [1]**



**Abstract**
*Background* Several outcomes of pregnancy after bariatric surgery are currently being studied.
*Methods* This cross-sectional, retrospective study evaluated the obstetric and perinatal outcomes of pregnancies in 19 women who underwent bariatric surgery, as well as the growth and development of their children, in the Southern Brazil.
*Results* Among these women, 11 children were born prior to surgery and 32 were born post-surgery. The mean time between the surgery and the first pregnancy was 42.96 months. Preterm newborns were more common among the pre-surgery childbirths. Regarding growth, normal weights were observed in 27.3 % of the children in the pre-surgery births and obesity was observed in 54.5 %. In contrast, normal weights were observed in 59.4 % of the children born during the postoperative period and obesity was observed in 31.2 %. The average excess weight that the women lost prior to pregnancy was 64.88. Speech delays were found in three male children evaluated using the Denver Developmental Screening Test II. A statistical association was found between the interval from the surgery to the pregnancy and the outcome of the questionable Denver II test results ($p$=0.011).
*Conclusions* Except for the large index of low birth weight, it can be concluded that pregnancy after bariatric surgery is safe. The growth rate was found to be adequate in the children born after the surgery, with reduced obesity. Although changes in speech development were detected, no factors were supported an association with pregnancy after bariatric surgery.

**Keywords** Pregnancy · Bariatric surgery · Pregnancy outcome · Growth · Child development

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## Introduction

Obesity has increased substantially worldwide. According to the World Health Organization (WHO), approximately 2.3 billion adults will be overweight by 2015, and more than 700 million will be obese [1].

The prevalence of obesity is particularly high among women. In the USA, in 2009, approximately 26 % of women presented with a body mass index (BMI) that indicated obesity [2]. Obesity has also increased significantly in Canadian women in the last 20 years, particularly among those between 20 and 39 years of age [3].

Obese women of reproductive age represent a specific group with added risks for complications linked to infertility [4–6] and to gestational diabetes [4–8], gestational hypertension, and preeclampsia during pregnancy [4–6, 8, 9]. Maternal obesity affects the development of the fetus and can cause congenital abnormalities [4], abnormal intrauterine growth, fetal malformation, and greater neonatal mortality [10–15]. Maternal obesity can also lead to adverse effects throughout a child's life, including obesity during development [16–18]. Because of the limited success of weight loss through behavioral means, bariatric surgery has become increasingly important in treating obesity [19, 20].

Approximately 84 % of bariatric surgeries are performed in women, and many of these women are at reproductive age

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[21, 22]. If we consider the recipients of bariatric surgery who are between 18 and 45 years of age, women represent 83 % of the patients who receive this type of surgery [23].

Bariatric surgery can help to reduce obesity-related complications during pregnancy [19, 23, 24]. Studies have described similar risks for prematurity [25–27] and fetal growth retardation [25, 26] among women who became pregnant after bariatric surgery compared with women in the general population or obese women.

Some authors have not found any differences or significant complications [26–33] in pregnancies that occurred in the general population and in women subjected to bariatric surgery [34]. However, some studies have described adverse perinatal results [35, 36] and vitamin deficiencies which may adversely affect the growth of the fetus [37–39]. Iron deficiency in women of reproductive age, calcium deficiency, and avitaminosis A, D and B12 [40] have also been considered factors that may cause fetal complications, such as premature birth, low birth weight, neonatal hypocalcemia, mental retardation, and neural tube defects [41, 42].

Recent studies have observed that women in the postsurgical group appear to have fewer pregnancy-related complications compared with pregnant obese women who have not undergone bariatric surgery [4, 26, 30, 43, 44].

Although several internationally published studies in the past several years have focused on pregnancies that occurred after bariatric surgery, there is still a little knowledge on long-term effects, and the findings of these studies remain controversial. Moreover, we are unaware of the research that addresses the growth and development of these children, which would be pertinent given the risk for neural tube defects and other possible changes that may be related to a lack of specific nutrients.

The present study was conducted to analyze the obstetric and perinatal outcomes of women who underwent bariatric surgery, as well as the growth and development of their children born before and after the surgery.

## Materials and Methods

This descriptive, exploratory, retrospective, and cross-sectional study was conducted to assess the obstetric and perinatal outcomes of the pregnancies of women who underwent bariatric surgery, as well as the growth and development of the children born before and after this procedure.

The study included 19 women who underwent bariatric surgery between 1999 and 2011 in the city of Maringa (in southern Brazil) and who became pregnant after this surgical intervention, as well as the children born after the surgery and the children conceived by the same mothers prior to the surgery.

Six hospitals in Maringa perform this procedure: a University Hospital, a philanthropic hospital, and four private hospitals. Each of these hospitals was authorized in the present research. In the period studied, 2352 women who had undergone bariatric surgery were identified; among them, 1901 (80.82 %) were of reproductive age (10–49 years old) at the time of surgery. Forty women who became pregnant after the surgical procedure were also identified. Among the latter group, one (2.5 %) woman died (by polytraumatism) and another one (2.5 %) reported the death of her son 3 years prior (at 3 months old); two (5.0 %) moved to other states; six (15.0 %) were not found at their addresses; and 11 (27.5 %) women refused to participate in the study, resulting in a total of 19 women. Together, these women gave birth to 11 children before bariatric surgery and 32 children after the surgical procedure; all children participated in the present research study.

During home visits, in accord with ethical recommendations, an interview was conducted using a research instrument that collected the sociodemographic characterization, gynecologic, obstetric, and surgical data of the mother and data related to the children. Weight and height were measured using a digital scale with a WISO W721 stadiometer with a capacity of 180 kg (396.82 lb).

The weight and height assessments were converted into BMI values, which were obtained using the following: formula BMI=weight (kg)/height ($m^2$). The BMI classification followed the WHO recommendations [45].

The children's birth weights (in grams) and heights (in centimeters) were reported by their mothers or verified from the prenatal records and were classified as low weight (<2500 g) or overweight (≥4000 g), according to the criteria established by the Centers for Disease Control and Prevention (2009) [46].

Regarding the gestational age (GA), the children were classified as preterm neonates if they were born before 37 gestational weeks [47].

This study also assessed the weights at time of the study of all children born before and after the bariatric surgeries. The values are presented as BMI values, which were obtained using the formula BMI=weight (kg)/height ($m^2$) following the WHO recommendations [45].

For the children whose heights and weights were found in the medical records, the WHO software along with at least five additional measurements [48] was used to assess their growth. Z scores and percentile values of weight for age (ZWA), height for age (ZHA), and weight for height (ZWH), as established by the WHO, were considered.

The growth assessments of the children without records containing weight and height data were performed with single data through multiple measurements on the day of the interview; the children were classified based on their BMIs by age and z score, as suggested by the WHO recommendations. For children 5–19 years old, overweight was considered to be a z score above +1 standard deviation (SD); obesity was a z score above +2 SD; skinniness was a z score below −2 SD; and extreme skinniness was a z score below −3 SD [49]. For children between 0 and 5 years old, this classification was based on the BMI by age, after a single measurement at the time of the interview and according to the WHO criteria [49].

Weight in early pregnancy was assessed using the Institute of Medicine (IOM) recommendations [50] and was classified based on the early gestation BMI, as follows: BMI<18.5 kg/m$^2$, insufficient weight; 18.5 to 24.9 kg/m$^2$, normal weight; 25.0 to 29.9 kg/m$^2$, overweight, and >30 kg/m$^2$, obesity. Gestational weight gain was also considered.

Gestational weight gain was calculated using data provided by the mothers, specifically their weights (in kilograms) in the early part of their pregnancies and heights (in centimeters) measured at the end of their pregnancies; gestational weight gain was defined as the difference between the final weight and the initial weight.

Excessive weight before pregnancy was calculated based on the difference between the actual weight prior to the surgery (kg)−the ideal weight (kg). The ideal weight was calculated using the formula 25 (ideal BMI value)×height (square meters). A BMI value of 25 corresponds to the superior limit of normality [51].

The loss of excessive weight after the surgery and before pregnancy was calculated using the following formula: weight before the surgery (kg)−weight in early pregnancy (kg)/weight before the surgery (kg)−ideal weight (kg)×100 [52], expressed as a percentage.

The neuropsychomotor development assessment in children from birth to 6 years of age was conducted using the Denver Developmental Screening Test II (DDST-II) [53]. The rights to the application of the DDST-II were acquired on the official website (www.denveriionline.com). For greater reliability and standardization, data were to entered into the website, which guarantees the anonymity and confidentiality of the data; the results were provided by the system, without interpretation bias from the researchers.

The DDST-II is composed of 125 items distributed into four areas: social and personal development (aspects of socialization of the child inside and outside of the family environment), language (sound production, capacity for recognition, understanding, and using language), fine motor skills (hand-eye coordination and handling of small objects), and gross motor skills (body motor control such as sitting and walking).

Each item of the assessment is classified as adequate (when the children perform the item as expected for their age), cautious (when they fail or refuse to perform an item that is usually performed by 75 to 90 % of children of the same age), or delay (when they fail or refuse to perform an item that is usually performed by >90 % of children of the same age).

In cases of preterm neonates (PTN), the GA was applied to the test to obtain a realistic expectation for a certain child, without underestimating functional ability when he/she is confronted with normal reference standards [53].

Data were tabulated with *Microsoft Office Excel 2007* software and were processed with *Statistica 7.0* and *Epi Info 3.5.2*. A descriptive analysis was conducted for quantitative variables by mean, standard deviation, and percentage; for categorical variables, a distribution by frequency and percentage was performed. For the variables of the DDST-II, Fisher's exact test was used, with the level of significance set at 5 %.

The study was approved by the Ethics Committee of the State University of Maringa (approval number 16826, April 30, 2012). Informed consent was obtained from all individual participants included in the study. In the case of minors, the informed consent was signed by the parent or guardian.

## Results

Of the 19 women studied, eight had children before the surgery (11); the women had a total of 32 children after undergoing the surgical procedure.

Seven (36.8 %) of the women presented with hypertension before the surgery; only one (5.3 %) presented with dyslipidemia, two (10.6 %) had sleep apnea, and three (15.8 %) reported vascular pathologies (varicose veins in the lower limbs). All women reported obesity as the primary impetus for the surgery. In all cases, these comorbidities improved completely. The sociodemographic characteristics and nutritional statuses during pregnancy of the women studied can be seen in Table 1 and the nutritional statuses before surgery and current gynecological data as well as excess weight lost after surgery until their first pregnancies, in the Table 2.

Of the 19 surgeries, 16 were performed with the silastic ring gastric Roux-en-Y bypass technique (84.2 %), one was performed with the sleeve gastrectomy technique (5.3 %), and two (10.6 %) women did not know the surgical procedure that they had undergone.

Most of the women studied (18–94.7 %) presented with a family history of at least two first degree relatives with obesity.

Among the pregnancies that occurred before the bariatric surgery (11), 4 (36.4 %) had been planned, and among the 32 pregnancies that occurred after the surgical procedure, 11 (34.4 %) had been planned.

Of the 32 children who were born after the surgical procedures, 23 underwent the DDST-II test, as they were within the indicated age group. Data from children born to mothers in the pre-and post-operative groups are described in Tables 3 and 4, and the overall performance in the DDST-I in Table 5.

Low birth weight was not associated with the time between the surgery and pregnancy ($p$=0.167), with gestational weight gain above normal levels ($p$=0.246) or with gestational weight gain below normal levels ($p$=0.500). There was also no association between the BMIs of overweight and obese

**Table 1** Distribution of the women who became pregnant after bariatric surgery, according to their sociodemographic characteristics and nutritional statuses during pregnancy, 1999–2011, Maringa, Parana, Brazil, 2014

| Variables | *n* value | % |
|---|---|---|
| Marital status $n=19$ | | |
| With partner | 17 | 89.5 |
| Without partner | 02 | 10.5 |
| Educational level (years) $n=19$ | | |
| 0 to 8 | 1 | 5.3 |
| 9 to 11 | 7 | 36.8 |
| ≥12 | 11 | 57.9 |
| Classification according to BMI[a] at surgery $n=19$ | | |
| Obesity class 2 (BMI=35.0–39.9) | 03 | 15.8 |
| Obesity class 3 (BMI≥40) | 16 | 84.2 |
| Risk of comorbidities, before surgery[b] $n=19$ | | |
| Severe | 03 | 15.8 |
| Very high | 16 | 84.2 |
| Classification according to BMI[a], gestational before surgery $n=11$ | | |
| Below normal | 1 | 9.1 |
| Normal weight (BMI 18.5–24.9) | 2 | 18.2 |
| Overweight (BMI 25.0–29.9) | 1 | 9.1 |
| Obesity class 1 (BMI 30.0–34.9) | 3 | 27.2 |
| Obesity class 2 (BMI 35.0–39.9) | 2 | 18.2 |
| Obesity class 3 (BMI≥40) | 2 | 18.2 |
| Classification according to weight gain in pregnancy before surgery $n=11$ | | |
| Below normal | 1 | 9.1 |
| Normal | 2 | 18.2 |
| Above normal | 8 | 72.7 |
| Classification by BMI[a], gestational after surgery $n=30$ | | |
| Normal weight (18.5–24.9) | 12 | 40.0 |
| Overweight (25.0–29.9) | 10 | 33.3 |
| Obesity class 1 (30.0–34.9) | 6 | 20.0 |
| Obesity class 2 (35.0–39.9) | 2 | 6.7 |
| Classification according to weight gain during pregnancy after surgery $n=30$ | | |
| Below normal | 16 | 53.3 |
| Normal | 10 | 33.3 |
| Above normal | 4 | 13.4 |
| Current classification of BMI[a] $n=19$ | | |
| Normal weight (18.5–24.9) | 2 | 10.5 |
| Overweight (25.0–29.9) | 5 | 26.3 |
| Obesity class 1 (30.0–34.9) | 8 | 42.2 |
| Obesity class 2 (35.0–39.9) | 4 | 21.0 |
| Current risk of comorbidities[b] $n=19$ | | |
| Medium | 2 | 10.5 |
| High | 5 | 26.3 |
| Moderate | 8 | 42.2 |
| Severe | 4 | 21.0 |

[a] Body mass index (BMI) expressed in (kg/m$^2$)

[b] According to the WHO

children in the early gestational group ($p$=0.108), the current overweight and obesity classification of the children, according to the WHO criteria ($p$=0.139), or the results of doubtful Denver II tests ($p$=0.256) using Fisher's exact test at a 95 % confidence interval (CI).

For the PTNs (<37 weeks), there was no statistically significant association between the current overweight classification and obesity, according to the WHO ($p$=0.620), and the results of doubtful DDST-II tests ($p$=0.547).

Using Fisher's exact test, no statistical association was observed in the interval between the surgery and pregnancy and the current overweight and obesity classifications of the children, according to the WHO criteria ($p$=0.619). However, there was an association found between the time between the surgery and pregnancy and the results of doubtful DDST-II tests ($p$=0.011) (Tables 1–5).

## Discussion and Conclusions

To the best of our knowledge, this study is the first to investigate the neuropsychomotor development and growth of children born to mothers who underwent bariatric surgery and comparing these children with those conceived before the surgical procedure.

The study results may generate prospective studies that aim for a greater comprehension of this effect of surgery on pregnancy, which is becoming more frequent and controversial amongst clinicians.

Certain recommendations should be followed during pregnancy after bariatric surgery. First, it is best when pregnancy is planned. The identification and correction of potential nutritional deficiencies that may occur in postoperative of bariatric surgery could be performed. Only 36.4 and 34.4 % of the pregnancies before and after the procedure, respectively, had been planned. During pregnancy, a post-surgical assessment of nutritional needs is essential to identify any nutritional deficiencies that may negatively affect fetal development as well as vitamin supplementation [54].

On the day of the surgery, 84.2 % of the women presented with level 3 obesity, according to their BMI values. Compared with the BMI classification on the day of the interview (current), obesity was noted in 63.2 % of the women and overweight in 26.3 %.

To reduce the risk of complications during pregnancy, weight loss before conception is advised by the American Congress of Obstetricians and Gynecologists (ACOG), and bariatric surgery is considered to be a promising treatment for this purpose [5].

Prior to surgery and early in their pregnancies, the obesity rate was 63.6 % in the referred women, according to their BMIs; 72.7 % of the women demonstrated weight gain above their ideal weights. In 26.7 % of cases, the women developed

**Table 2** Distribution of the women who underwent bariatric surgery, according to their nutritional statuses before surgery and current gynecological data, as well as excess weight loss after surgery until their first pregnancies, 1999–2011, Maringa, Parana, Brazil, 2014

| Variables | N | Mean | Minimum | Maximum | SD* |
|---|---|---|---|---|---|
| Age at surgery | 19 | 27.63 | 17.00 | 37.00 | 4.92 |
| Preoperative weight (kg) | 19 | 123.98 | 98.70 | 165.00 | 19.67 |
| BMI[a] preoperative (kg/m$^2$) | 19 | 45.11 | 35.43 | 61.73 | 6.29 |
| Previous bariatric surgery | | | | | |
| Early pregnancy maternal weight (kg) | 11 | 90.00 | 50.00 | 125.00 | 24.45 |
| BMI[a] gestational (kg/m$^2$) | 11 | 31.21 | 17.72 | 42.19 | 7.93 |
| Mother's weight at the end of pregnancy (kg) | 11 | 108.36 | 75.00 | 138.00 | 17.07 |
| Weight gain during pregnancy (kg) | 11 | 18.27 | 5.00 | 50.00 | 15.02 |
| First child's birth weight (grams) | 8 | 3416.25 | 1000.00 | 4100.00 | 1013.32 |
| Second child's birth weight (grams) | 3 | 2970.00 | 3580.00 | 4380.00 | 400.37 |
| After bariatric surgery | | | | | |
| Early pregnancy maternal weight (kg) | 30 | 73.18 | 55.00 | 107.00 | 14.16 |
| BMI[a] gestational (kg/m$^2$) | 30 | 27.04 | 19.49 | 38.10 | 4.92 |
| Mother's weight at the end of pregnancy (kg) | 30 | 79.73 | 48.00 | 119.00 | 15.51 |
| Weight gain during pregnancy (kg) | 30 | 6.23 | −18.00 | 12.00 | 5.24 |
| First child's birth weight (grams) | 22 | 2935.90 | 1900.00 | 3950.00 | 632.84 |
| Second child's birth weight (grams) | 6 | 2680.83 | 1500.00 | 3900.00 | 841.90 |
| Third child's birth weight (grams) | 2 | 2725.00 | 2450.00 | 3000.00 | 388.90 |
| Current mother's age (years) | 19 | 37.05 | 30.00 | 45.00 | 4.53 |
| Current mother's weight (kg) | 19 | 84.89 | 62.60 | 117.90 | 12.93 |
| Current mother's body mass index (kg/m$^2$) | 19 | 31.28 | 24.49 | 38.30 | 4.45 |
| Early sexual activity age (years) | 19 | 19.15 | 12.00 | 32.00 | 4.99 |
| Age at menarche (years) | 19 | 12.15 | 9.00 | 15.00 | 1.46 |
| Excess weight lost (%)[b] | | | | | |
| First pregnancy after surgery | 19 | 64.88 | 22.89 | 102.00 | 17.07 |
| Second pregnancy after surgery | 13 | 72.65 | 39.74 | 103.00 | 23.11 |
| Third pregnancy after surgery | 2 | 68.43 | 51.02 | 85.85 | 24.62 |
| Time between surgery and pregnancy (months) | 32 | 42.96 | 3.00 | 114.00 | 29.05 |

[a] BMI

[b] One of the mothers had fourth and fifth sons, with 63.37 % loss of excess weight in the early pregnancies and weights of 1000.00 and 3125.00 g, respectively

*SD

obesity early in pregnancies that occurred after they underwent surgery and below normal weight gain was observed in 53.3 % of the pregnancies.

Weight gain during gestation may directly affect the immediate and future health of the mother and child. The IOM has published the recommendations for adequate weight gain

**Table 3** Distribution of bariatric surgery, according to the birth weights of the children born to mothers in the pre-and postoperative groups, 1999–2011, Maringa, Parana, Brazil, 2014

| Weight | Before surgery $n$=11 | | | | | | After surgery $n$=32 | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight | | Normal weight | | Overweight | | Underweight | | Normal weight | | Underweight | |
| | $n$ | % | $n$ | % | $n$ | % | $n$ | % | $n$ | % | $n$ | % |
| First child | 1 | 9.1 | 5 | 45.4 | 2 | 18.2 | 6 | 18.7 | 16 | 50.0 | – | – |
| Second child | – | – | 2 | 18.2 | 1 | 9.1 | 2 | 6.3 | 4 | 12.5 | – | – |
| Third child | – | – | – | – | – | – | – | – | 2 | 6.3 | – | – |
| Fourth child | – | – | – | – | – | – | 1 | 3.1 | – | – | – | – |
| Fifth child | – | – | – | – | – | – | – | – | 1 | 3.1 | – | – |

**Table 4** Distribution of the number of children of the women who became pregnant after bariatric surgery, according to the characteristics of sex, gestational age, delivery mode, and current rating of the child's growth, 1999–2011, Maringa, Parana, Brazil, 2014

| Variables | Child before surgery *n*=11 | | Child after surgery *n*=32 | |
|---|---|---|---|---|
| | *n* | % | *n* | % |
| Sex | | | | |
| Male | 6 | 54.5 | 17 | 53.1 |
| Female | 5 | 45.5 | 15 | 46.9 |
| Gestational age | | | | |
| <37 weeks | 1 | 9.1 | 6 | 18.8 |
| ≥37 weeks | 10 | 90.9 | 26 | 81.2 |
| Birth weight | | | | |
| Underweight | 1 | 9.1 | 9 | 28.1 |
| Normal weight | 7 | 63.6 | 23 | 71.9 |
| Overweight | 3 | 27.3 | – | – |
| Delivery type | | | | |
| Cesarean | 11 | 100.0 | 30 | 93.7 |
| Normal | – | – | 2 | 6.3 |
| Current growth classification[a] | | | | |
| Normal weight | 3 | 27.3 | 19 | 59.4 |
| Overweight | – | – | 1 | 3.1 |
| Obesity | 6 | 54.5 | 10 | 31.2 |
| Ignored | 2 | 18.2 | 2 | 6.3 |

[a] According to the WHO (2007)

during pregnancy based on the BMI in early gestation. For low-weight women (BMI<18.5 kg/m$^2$), a gestational weight gain of 12.7–18.2 kg is recommended; for normal weight women (BMI 18.5–24.9 kg/m$^2$), a weight gain between 11.3 and 15.8 kg is recommended. Concerning overweight women (BMI 25–29.9 kg/m$^2$), the IOM recommends a total weight gain of 6.8–11.3 kg [50]. However, gestational weight gain below these recommendations does not appear to negatively affect the growth of the fetus or neonatal outcomes.

There is evidence of an association between gestational weight and higher birth weight [55], other than postpartum weight retention [55, 56]. This association is also observed when inadequate weight gain reflects a lower birth weight.

A high gestational weight gain elevates the risks for pre-eclampsia [57, 58], gestational diabetes [59], and surgical delivery in addition to an increased risk for obesity.

However, low gestational weight, in turn, is associated with prematurity and low birth weight [60]. Several studies have demonstrated that overweight women who gained 2.7–6.4 kg during gestation have children with similar fetal, perinatal, and neonatal growth, and have a higher postpartum weight retention than overweight women who gained weight within the recommended range [61, 62].

A limitation of this study is that the IOM does not differentiate obesity; it classifies women with BMIs>30 kg/m$^2$ as obese and recommends a weight gain of 5–9.1 kg during gestation. Several studies associate excessive weight gain during gestation with a greater risk of overweight/obesity in children and adolescents [58, 63].

The American Congress of Obstetricians and Gynecologists (ACOG) recommends that professionals who perform prenatal examinations should determine the BMI on the first visit/consultation; discuss the adequate weight, diet, and exercise with the patients; and address these themes periodically during pregnancy. Thus, the gestational weight gain could be planned in early pregnancy, aiming to the ideal weight gain during pregnancy [64].

Low birth weight has been found in 9.1 % of the children born before the surgery, which is less than the 28.1 % of children born after the surgical intervention. Nevertheless, the excessive birth weight, verified in the first cases (27.3 %), has not been found in children who were born after the surgery.

Birth weight is usually related to maternal BMI. Studies have demonstrated a reduction in the average birth weight after bariatric surgery [18, 38, 65].

According to some researchers, low birth weight has been associated with bariatric surgery and intrauterine growth reduction [4, 25, 33, 38]. However, other authors have not observed any differences in the rates of delay of intrauterine growth and low birth weight in children born before and after the surgery [30].

A higher percentage of PTNs has been found among children born after the bariatric surgery (6–18.8 %) than among those born before the surgery (1–9.1 %). In a systematic review, three controlled cohort studies have found that gestations after bariatric surgery present the same risks for premature birth [25–27] or fetal growth restriction [25, 26] compared with gestations in the general population or in obese women.

Another systematic review on pregnancy and fertility after bariatric surgery has concluded that the rates of adverse neonatal outcomes may be lower in women who were subjected to bariatric surgery than in obese women but describes the need for further studies [23].

The values found in this study with respect to the frequency of Caesarian sections, both for deliveries before the bariatric surgery (100 %) and those after the surgical procedure, (93.7 %) were high. Other studies have described lower Caesarian section indices (27.5 %) after weight loss surgeries [66].

Some studies have described increased Caesarian section rates in women subjected to bariatric surgery [28, 30], and the surgery itself has been considered an independent risk factor for Caesarian section [23, 28, 34, 66, 67]. However, another study has demonstrated that the rates for these patients are similar to those of the general population [33].

**Table 5** Overall performance of the children born to mothers who underwent bariatric surgery, according to birth and maternal variables using the DDST-II, 1999–2011, Maringa, Parana, Brazil, 2014

| | Outcomes of the DDST-II, $n$=23 | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Personal-social | | Language | | Fine motor | | Gross motor | |
| | N[a] | S[b] | N[a] | S[b] | N[a] | S[b] | N[a] | S[b] |
| Children variables | | | | | | | | |
| Sex | | | | | | | | |
| Male | 10 | – | 7 | 3 | 10 | – | 10 | – |
| Female | 13 | – | 13 | – | 13 | – | 13 | – |
| Delivery | | | | | | | | |
| Cesarean | 22 | – | 19 | 3 | 22 | – | 22 | – |
| Vaginal | 1 | – | 1 | – | 1 | – | 1 | – |
| Birth weight | | | | | | | | |
| Underweight | 8 | – | 8 | – | 8 | – | 8 | – |
| Normal weight | 15 | – | 12 | 3 | 15 | – | 15 | – |
| Gestational age | | | | | | | | |
| Preterm birth | 4 | – | 4 | – | 4 | – | 4 | – |
| Term newborn | 19 | – | 16 | 3 | 19 | – | 19 | – |
| Current growth classification[a] $n$=22 | | | | | | | | |
| Normal weight | 14 | – | 13 | 1 | 14 | – | 14 | – |
| Obesity | 8 | – | 6 | 2 | 8 | – | 8 | – |
| Interval between surgery and pregnancy | | | | | | | | |
| ≤18 months | 2 | – | – | 2 | 2 | – | 2 | – |
| ≥19 | 21 | – | 20 | 1 | 21 | – | 21 | – |
| Maternal variables $n$=19 | | | | | | | | |
| Educational level (years) | | | | | | | | |
| 0 to 8 | 1 | – | 1 | – | 1 | – | 1 | – |
| 9 to 11 | 7 | – | 7 | – | 7 | – | 7 | – |
| ≥12 | 11 | – | 8 | 3 | 11 | – | 11 | – |
| Age at surgery | | | | | | | | |
| >25 years | 15 | – | 12 | 3 | 15 | – | 15 | – |
| ≥25 years | 4 | – | 4 | – | 4 | – | 4 | – |
| Marital status | | | | | | | | |
| With partner | 21 | – | 19 | 2 | 21 | – | 21 | – |
| Without partner | 2 | – | 1 | 1 | 2 | – | 2 | – |
| Gestational weight gain=22 | | | | | | | | |
| Below normal | 9 | – | 8 | 1 | 9 | – | 9 | – |
| Normal | 9 | – | 8 | 1 | 9 | – | 9 | – |
| Above normal | 4 | – | 3 | 1 | 4 | – | 4 | – |
| Early pregnancy BMI classification $n$=22 | | | | | | | | |
| Normal | 8 | – | 7 | 1 | 7 | – | 7 | – |
| Overweight | 7 | – | 5 | 2 | 7 | | 7 | |
| Obesity | 7 | – | 7 | – | 7 | – | 7 | – |
| Excess weight lost (%) $n$=18 | | | | | | | | |
| >50 | 16 | – | 13 | 3 | 16 | – | 16 | – |
| ≤50 | 2 | – | 2 | – | 2 | – | 2 | – |

[a] Normal

[b] Suspect

The current growth classification, based on the BMI and assessed in accord with the WHO recommendations, has described normal weight in three (27.3 %) children and obesity in six (54.5 %) children born during the pre-surgical period when the BMIs of the mothers were higher. After the weight loss initiated by the bariatric surgery, normal weight was found in 59.4 % (19) of the children and reduced obesity rates (31.2 %) were observed.

A study of the long-term follow-up of such patients has demonstrated that maternal weight loss after the surgery has a lasting effect on the developing child and decreases the rates of obesity to 52 % and that of severe obesity to 45 % [18].

The average time between bariatric surgery and pregnancy was 42.96±29.05 months. The shortest interval observed was 3 months, and the longest was 114 months.

After the surgical procedure, there is typically a period of rapid weight loss in the first 6–18 months [26]. Thr pregnancy in this period may be worrisome because the nutritional deficiencies resulting from the weight loss may occur (to the detriment of the increasing needs of the fetus during pregnancy) [68].

Thus, some authors have recommended an interval of 12–24 months between bariatric surgery and conception [5].

A study on the comparison of the pregnancy that occurred in the first year after the surgery and the pregnancy after 1 year did not find any significant differences in the results, and the time interval between these events has not been associated with complications during pregnancy [69]. Several other studies corroborate this statement and have not demonstrated any differences in neonatal complications in conceptions that occurred during or after the period of rapid weight loss [4, 25, 26, 29, 66].

Several authors suggest a period of at least 1 year after the bariatric surgery, until new and more comprehensive studies are conducted to assess the perinatal outcomes [5, 23, 31, 66, 69].

Bariatric surgery is an important form of treatment for morbid obesity that is refractory/noncompliant to habitual medical therapy because it causes a long-term loss of >60 % excessive weight and generally a complete resolution of various comorbidities [19].

In addition to a reduction in or improvement of comorbidities, another consequence of weight loss is the improvement in self-esteem and quality of life [70].

The average excessive weight loss in this study until the time of pregnancy was 64.88 % and varied from 22.89 to 103 %.

As for the DDTS-II, three children born from mothers who had undergone bariatric surgery demonstrated delay items entirely on the left side of the age line, which has led to questionable interpretation of the test. All three of these children have failed (delay item) the aspect of comprehensible speech, which is related to language. Consonant, vowel, or even syllable changes (consonant/vowel) have been observed. To interpret the DDST-II, a delay is considered when a child fails or refuses an item that falls entirely on the left side of the age line; that is, the child failed or refused an item that 90 % of children in the standardized sample are able to perform at a younger age. Caution, in turn, is necessary when a child fails or refuses an item in which the line age falls between 75 and 90 %. This process is used because >75 % of the children in the standardized sample can perform the item at a younger age than those tested [53].

A normal test is considered when there is no item that suggests a delay and a cautious item, at least. When two or more cautious and/or one or more delays are verified, the test is considered doubtful [53]. In cases where tests are considered doubtful, repeating the test is recommended within 1–2 weeks to account for certain factors, such as fatigue, fear, and disease [53].

However, in this study, a second test has not been administered because all three children who showed this delay item in language had presented with the issue over a long period of time and were being treated with speech-language pathologists.

In a cross-sectional study in which the authors aimed to verify the influence of birth weight and gestational age on the acquisition of language and on the neurodevelopment of children, using the DDST-II (among other tests), the authors have concluded that children with low birth weight who were born with reduced gestational age presented a greater probability of a delay in developing language [71].

All three children who were deemed doubtful in terms of the results of this test were male, born from mothers over 25 years of age with a high level of schooling, delivered at full-term by Caesarian section, and had normal birth weights. One child was born within 3 months interval between the surgery and pregnancy, and the other two were born within 14 and 114 months. The BMIs of the mothers in early pregnancy were within the range of overweight in two cases and normal in the other one. The percentage of excessive weight loss after the surgery until the pregnancy was >50 % in the three pregnancies. Gestational weight gain varied a significant amount: It was normal for one child, below normal for another, and above normal for the third child.

Some studies have found the associations between disorders in language development and maternal nutritional deficiencies.

In contrast with the low rates of mortality resulting from the decrease in surgical complications over the years [19], there is an increase in the risk of metabolic complications resulting from nutritional deficiencies after the surgery [71], which could explain the disorders of language presented by the children of this research. Many other maternal and fetal complications have been reported, such as fetal intracranial hemorrhage, which results from a maternal deficiency of vitamin K, caused by vomiting after the surgery [72], and neural tube defects resulting from folic acid deficiency [41].

Certain maternal deficiencies are reportedly related to language disorders, such as a lack of vitamin D during pregnancy.

The risk of women with vitamin D deficiency during pregnancy having a child with difficulties in language is twice that of women with normal vitamin D levels [73].

This research has some limitations that should be considered, such as the small number of cases, in spite of the long study period (13 years), were studied the children born after the surgery and the children conceived by the same mothers prior to the surgery, as well as the predominance of only one type of surgical technique. Because this study is retrospective, there are difficulties in interpreting some data related to the need for measurements during pregnancy and the detection of changes that can justify the results. Another limitation is the lack of a systematic assessment of the neuropsychomotor development of children by health services, which hinders a comparative analysis between the pattern of development of children born before and after this type of surgical intervention.

Despite the aforementioned limitations of the current research, we believe that this study holds merit in elucidating areas for future research. In particularly, present findings support the benefit of investigating the influence of bariatric surgery on perinatal outcomes, particularly for disorders in language development. Because this surgery is relatively a new procedure, the number of operations is increased and there are many uncertainties concerning women who underwent bariatric surgery and who become pregnant after the procedure. More evidence is required, as well as a larger number of cases and long-term follow-up.

This study is in accordance with the ethical standards and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. It was approved by the Ethics Research Committee of the State University of Maringa.

Informed consent was obtained from all individual participants included in the study.

**Conflict of interest** The authors declare that they have no conflict of interest.

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