

## **Gestational weight gain and breastfeeding practices in relation to offspring body mass index among Amazonian young children**

**Short title:** Maternal weight, breastfeeding and child weight

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### **Competing Interests**

None of the authors have conflicts of interest in relation to this manuscript.

### **Data availability statement**

All relevant data are within the paper and the original, anonymized database, are available from the corresponding author on reasonable request.

## **Abstract**

**Objective:** Excessive weight gain during childhood has been considered an early life risk factor for chronic disease in the long term. We examined the role of excessive gestational weight gain (GWG) and breastfeeding (BF) practices with the offspring's body mass index-for-age z-score (zBMI) at 2 years.

**Methods:** Data from 743 Amazonian young children of the MINA-Brazil population-based birth cohort study was used. Linear regression models were run to estimate the associations between excessive GWG and BF practices (exclusive breastfeeding, EBF <3 months of age and BF <1 year) with zBMI.

**Results:** Excessive GWG and BF <1 year were associated with an adjusted 0.24 units (95% CI: 0.08, 0.41) and 0.28 units (95% CI: 0.12, 0.44) higher zBMI at age 2 years, respectively.

**Conclusions:** Gain excessive weight during pregnancy and shorter BF duration (<1y) were associated with a higher body mass index at 2 years of age among Brazilian Amazonian children.

**Keywords:** gestational weight gain, breastfeeding, body mass index, adiposity, childhood

## INTRODUCTION

Childhood excessive weight gain, which predisposes to obesity and a higher risk of non-communicable diseases in later life, is increasingly affecting low- and middle-income countries. The prevalence estimates of overweight worldwide, in Latin America, and among Brazilian children under 5 years in 2020 were 5.7%, 7.5%, and 7.3%, respectively, without considering the impact of the COVID-19 pandemic (United Nations Children's Fund & World Health Organization [WHO], 2021).

Evidence suggests that the origins of childhood excess weight start in the early stages of life (Woo Baidal et al., 2016). During pregnancy, excessive gestational weight gain (GWG) is related to greater childhood adiposity (Voerman et al., 2019), affecting a child's body mass index (BMI) across three generations, indirectly through the grandmother and directly through the mother (Schneider et al., 2021). In the postnatal period, breastfeeding (BF) was suggested as a protective factor against non-communicable diseases, including overweight and obesity later in life (Horta et al., 2015), despite controversies (Kramer et al., 2007; Zheng et al., 2020).

BMI reduction at an early age is a starting point towards lessening childhood excessive weight gain. Thus, a better insight of modifiable early nutrition factors is essential, particularly in low-income populations, with limited access to healthcare, and precarious environmental conditions. However, despite childhood overweight relevance in public health, information on nutritional status of Amazonian infants are scarce and data available comes mainly from cross-sectional surveys (Cunha et al., 2017). Given the importance of perinatal factors for child health and the lack of longitudinal studies in remote areas, this study aimed to examine the role of excessive GWG and BF practices in BMI at 2 years of age in the first population-based birth cohort

conducted in the Brazilian Amazon. We hypothesized that both adequate GWG and longer BF practices could inversely affect child BMI.

## **METHODS**

The MINA-Brazil study (Maternal and Child Health and Nutrition in Acre) design had been described previously (Cardoso et al., 2020). Between July 2015 and June 2016, all women who gave birth in the only maternity ward in Cruzeiro do Sul, Acre State, and agreed to participate in the study (n=1246) were interviewed after delivery to obtain their baseline information. Follow-up assessment visits were performed at 6 months, 1 year, and 2 years to collect data on infant feeding practices and anthropometric status. In the present study, we analyzed data from 743 mother-infant dyads out of the 868 participants in the 2-year follow-up visit. Women with incomplete data on GWG (n=45), children born preterm (n=64), twins (n=14), babies with contraindications to breastfeeding (n=1, HIV-positive mother), and incomplete data on weight at 2 years (n=1) were excluded. All the participants provided informed consent at enrollment. This study was approved by the ethical review board of the School of Public Health, University of São Paulo, Brazil (number 872.613, 13 November 2014).

The exposures of interest were the GWG and BF practices. The difference between maternal weight at delivery (collected from hospital records) and pre-pregnancy weight (obtained from prenatal cards) was used to estimate the GWG. Based on the pre-pregnancy BMI categories, the estimated GWG of women who gave birth at  $\geq 37$  weeks of gestational age was assessed according to the adherence of the Institute of Medicine GWG guidelines (IOM, 2009), as adopted by the Brazilian Ministry of Health, and further categorized as excessive or not. In the follow-up interviews, which were conducted by telephone in the first month and by in-person visits

afterward, mothers were asked about their current BF status (yes or no), and child's age when stopped BF. At 1- and 6-month assessments, using recall since birth, mothers reported the age of introduction of weaning foods. A list of foods commonly offered to infants (water, tea, fruit juice, cow milk, formula, other liquids, semi-solids, and solid foods) was provided. At 1- and 2-year assessments, a 24-h food recall based on the previous day consumption was administered. Children were considered exclusively breastfed if they received breast milk with no other food or drink. Feeding practices were categorized as exclusive breastfeeding (EBF,  $<3$  and  $\geq 3$  months) and BF duration ( $<1$  and  $\geq 1$  year).

The outcome of interest was the children's BMI at 2 years. Children's length and weight were determined using standardized procedures, and the age- and sex-specific z-scores for BMI (zBMI) were computed based on the WHO Child Growth Standards (WHO, 2006).

The participants' baseline characteristics at 2-year follow-up were similar to those lost to follow-up, although study families retained at 2 years were wealthier (Cardoso et al., 2020).

The independent predictors of the outcome were identified by comparing distributions (means and standard deviations, SD) using *t-test* or one-way ANOVA. Covariates were selected for multiple models if they were associated with the zBMI in the crude analysis at  $P < 0.20$ . Linear regression models were used to estimate the associations between excessive GWG and BF feeding practices with zBMI. The results were expressed as crude and adjusted mean differences with 95% confidence intervals (CI). Adjustment for covariates included maternal schooling, self-reported skin color, wealth index, primiparity, pre-pregnancy BMI, antenatal care visits, and child sex. The relation between BF practices and zBMI was adjusted for GWG and birth weight. All analyses were conducted using Stata 15.0 (StataCorp), with the significance level set at 5%.

## RESULTS

Overall, 36.5% of the women experienced excessive GWG. Although 63.6% exclusively breastfed their children for less than 3 months, 70% continued to breastfeed for up to 1 year or more. At the 1-year assessment, most children had consumed at least one processed food (90%). At the 2-year assessment, the infants' mean age was 23.8 (SD 1.4) months. The mean zBMI was 0.47 (SD 1.05), and 7.3% were overweight (zBMI for age  $\geq 2$ ). EBF and complementary food consumption were not significantly associated with child BMI (Table 1).

Offspring of women with excessive GWG or those who breastfed for less than 1 year had an adjusted mean zBMI 0.24 (95% CI: 0.08, 0.41) and 0.28 higher (95% CI: 0.12, 0.44), respectively, when compared with their counterparts (Table 2). These associations were not observed for overweight condition (data not shown).

## DISCUSSION

Our results confirmed the predictive role of excessive GWG in offspring body weight. The transmission of excessive weight during pregnancy to the infant through intrauterine development conditions is hardly disengaged from cultural, environmental, and behavioral attributes (Skrypnik et al., 2019). However, a recent meta-analysis of cohort studies from developed countries showed that the proportions of the prevalence of overweight and obesity in children aged 2 to 5 years attributable to excessive GWG was 11.4% (Voerman et al., 2019). Conveniently, actions to prevent child excess weight should start at least during the fetal period.

Our results also showed that shorter BF duration (<1y) was associated with a higher zBMI at 2 years. Similarly, in a prospective cohort of Australian children, infants who were breastfed for more than 6 months had a significantly lower zBMI at all ages from 3 to 60 months, compared

with those who were breastfed for a shorter period (Zheng et al., 2020). Yet, studies on the effect of BF promotion interventions on child growth observed a modest reduction in zBMI (Giugliani et al., 2015), or no effect (Kramer et al., 2007). Despite the mixed results, our findings support the potential influence of longer BF duration on lower adiposity in this population since household wealth index, maternal education, prepregnant BMI, and childbirth weight did not attenuate the magnitude of the association.

However, we did not observe a significant association of early introduction of cow milk or solid food and UPF consumption with child BMI. Similarly, Bell et al., (2018) found no association between timing of solid food and risk of childhood obesity at 24 to 36 months. Previous moderate evidence indicated no association between complementary feeding and body composition (English et al., 2019). Conversely, UPF high-rate intake in our population may have led to non-existent association.

The strengths of our study include the use of data from a population-based birth cohort, which prevents reverse causation and recall biases; child anthropometric measurement by trained staff rather than self-reported; and prospective collection of BF information, which reduces misclassification. Limitations include possible selection bias due to losses to follow-up and uncertain generalizability to populations with different GWG and child BMI characteristics. Furthermore, we could not assess the associations with EBF at 6 months given the overall short duration of EBF; also, we cannot rule out residual confounding on the BF-BMI association by unmeasured factors such as child energy intake and physical activity.

Our estimates can guide public health policies by considering specific characteristics of Amazonian mother-child pairs for planning targeted interventions to prevent higher overweight rates in childhood.



**CONCLUSION**

In this study, excessive GWG and shorter BF duration were related to increased zBMI at 2 years. Our findings emphasize that actions to prevent excessive weight gain in childhood should start during pregnancy. In view of the positive influence of breastfeeding on childhood weight, our results reinforce WHO recommendations for the promotion, support, and protection of EBF for 6 months and longer BF duration.

## REFERENCES

- Bell, S., Yew, S. S. Y., Devenish, G., Ha, D., Do, L., & Scott, J. (2018). Duration of Breastfeeding, but Not Timing of Solid Food, Reduces the Risk of Overweight and Obesity in Children Aged 24 to 36 Months: Findings from an Australian Cohort Study. *Int J Environ Res Public Health*, *15*(4).
- Cardoso, M., Matijasevich, A., Malta, M. B., Lourenco, B. H., Gimeno, S. G. A., Ferreira, M. U., & Castro, M. C. (2020). Cohort profile: the Maternal and Child Health and Nutrition in Acre, Brazil, birth cohort study (MINA-Brazil). *BMJ Open*, *10*(2), e034513.
- Cunha, M. P. L., Marques, R. C., & Dórea, J. G. (2017). Child Nutritional Status in the Changing Socioeconomic Region of the Northern Amazon, Brazil. *Int J Environ Res Public Health*, *15*(1).
- English, L. K., Obbagy, J. E., Wong, Y. P., Butte, N. F., Dewey, K. G., Fox, M. K., Greer, F. R., Krebs, N. F., Scanlon, K. S., & Stoody, E. E. (2019). Timing of introduction of complementary foods and beverages and growth, size, and body composition: a systematic review. *The American journal of clinical nutrition*, *109*(Suppl\_7), 935S–955S.
- Giugliani, E. R., Horta, B. L., Loret de Mola, C., Lisboa, B. O., & Victora, C. G. (2015). Effect of breastfeeding promotion interventions on child growth: a systematic review and meta-analysis. *Acta Paediatr*, *104*(467), 20-29.
- Horta, B. L., Loret de Mola, C., & Victora, C. G. (2015). Long-term consequences of breastfeeding on cholesterol, obesity, systolic blood pressure and type 2 diabetes: a systematic review and meta-analysis. *Acta Paediatr*, *104*(467), 30-37.
- Institute of Medicine, & National Research Council. (2009). *Weight gain during pregnancy: reexamining the guidelines*. National Academies Press.
- Kramer, M. S., Matush, L., Vanilovich, I., Platt, R. W., Bogdanovich, N., Sevkovskaya, Z., . . . Shapiro, S. (2007). Effects of prolonged and exclusive breastfeeding on child height, weight, adiposity, and blood pressure at age 6.5 y: evidence from a large randomized trial. *Am J Clin Nutr*, *86*(6), 1717-1721.
- Schneider, B. C., Menezes, A. M. B., Wehrmeister, F. C., & Gonçalves, H. (2021). Gestational weight gain and childhood body mass index across three generations: Results from the 1993 Pelotas (Brazil) Birth Cohort. *Pediatr Obes*, *16*(6), e12760.
- Skrypnik, D., Bogdański, P., Zawiejska, A., & Wender-Ożegowska, E. (2019). Role of gestational weight gain, gestational diabetes, breastfeeding, and hypertension in mother-to-child obesity transmission. *Pol Arch Intern Med*, *129*(4), 267-275.
- United Nations Children’s Fund, & World Health Organization. (2021). Levels and trends in child malnutrition: key findings of the 2021 edition of the joint child malnutrition estimates. In T. W. B. International Bank for Reconstruction and Development (Ed.). Geneva: World Health Organization; 2021.
- Voerman, E., Santos, S., Patro Golab, B., Amiano, P., Ballester, F., Barros, H., . . . Jaddoe, V. W. V. (2019). Maternal body mass index, gestational weight gain, and the risk of overweight and obesity across childhood: An individual participant data meta-analysis. *PLoS Med*, *16*(2), e1002744.
- Woo Baidal, J. A., Locks, L. M., Cheng, E. R., Blake-Lamb, T. L., Perkins, M. E., & Taveras, E. M. (2016). Risk Factors for Childhood Obesity in the First 1,000 Days: A Systematic Review. *Am J Prev Med*, *50*(6), 761-779.
- World Health Organization. (2006). Child Growth Standards based on length/height, weight and age. *Acta Paediatr Suppl*, *450*, 76-85.
- Zheng, M., Cameron, A. J., Birken, C. S., Keown-Stoneman, C., Laws, R., Wen, L. M., & Campbell, K. J. (2020). Early Infant Feeding and BMI Trajectories in the First 5 Years of Life. *Obesity (Silver Spring)*, *28*(2), 339-346.

**Table 1.** Maternal and child characteristics by body mass index-for-age z score (zBMI)<sup>a</sup> at 2-year follow-up (n 743). The MINA-Brazil birth cohort.

<b>Exposures variables</b>	<b>Participants n (%)<sup>b</sup></b>	<b>zBMI Mean (SD)</b>	<b>p<sup>c</sup></b>
<b>Maternal schooling</b>			0.01
≤9 y	205 (28.1)	0.29 (1.03)	
10   -   12 y	381 (52.2)	0.49 (1.06)	
>12 y	144 (19.7)	0.61 (1.05)	
<b>Self-report skin color</b>			0.05
White	96 (13.2)	0.26 (0.86)	
Black	28 (3.8)	0.24 (1.19)	
Mulatto	567 (77.7)	0.49 (1.05)	
Indigenous and yellow	39 (5.3)	0.72 (1.29)	
<b>Wealth index</b>			0.07
1 <sup>st</sup> lower	143 (19.6)	0.29 (0.91)	
2 <sup>nd</sup>	274 (37.5)	0.47 (1.12)	
3 <sup>rd</sup> higher	313 (42.9)	0.53 (1.04)	
<b>Primiparity</b>			0.19
No	443 (60.7)	0.42 (1.07)	
Yes	287 (39.3)	0.52 (1.02)	
<b>Pre-pregnancy BMI</b>			<0.01
Underweight	50 (6.7)	0.24 (0.99)	
Normal weight	418 (56.3)	0.36 (1.01)	
Overweight	202 (27.2)	0.61 (1.10)	
Obesity	73 (9.8)	0.79 (1.06)	
<b>Antenatal care visits</b>			0.02
<6 visits	126 (17.0)	0.27 (1.04)	
≥6 visits	616 (83.0)	0.50 (1.05)	
<b>Gestational weight gain<sup>d</sup></b>			<0.01
Not excessive	486 (65.4)	0.35 (1.04)	
Excessive	257 (34.6)	0.69 (1.02)	
<b>Child sex</b>			0.92
Female	369 (49.7)	0.46 (1.00)	
Male	374 (50.3)	0.47 (1.10)	
<b>Birthweight</b>			<0.01
<2500 g	19 (2.6)	0.24 (0.63)	
≥2500 - <4000 g	669 (90.0)	0.43 (1.06)	
>4000 g	55 (7.4)	1.01 (0.89)	
<b>Exclusive Breastfeeding</b>			0.47

EBF $\geq$ 3m	245 (36.3)	0.42 (1.13)	
EBF <3m	429 (63.7)	0.49 (1.03)	
<b>Breastfeeding</b>			<0.01
BF $\geq$ 1 y	520 (70.0)	0.39 (1.07)	
BF <1 y	223 (30.0)	0.64 (0.97)	
<b>Age at introduction of cow milk or solid food</b>			0.30
<4 m	305 (56.1)	0.50 (1.01)	
4 m   - 6m	159 (29.2)	0.35 (1.04)	
$\geq$ 6m	80 (14.7)	0.39 (1.11)	
<b>Cow's milk consumption at the 1-year follow-up</b>			0.36
No	542 (73.1)	0.45 (1.06)	
Yes	200 (26.9)	0.53 (1.01)	
<b>Ultra-processed foods consumption in the 1-year follow-up<sup>e</sup></b>			0.89
Not consumed	75 (10.1)	0.52 (1.28)	
1 to 2 UPFs	347 (46.7)	0.46 (1.06)	
3 or more UPFs	321 (43.2)	0.46 (0.98)	

Abbreviations: GWG, gestational weight gain; EBF, exclusive breastfeeding; BF, breastfeeding; BMI, body mass index; m, months; y, year; g, grams; UPFs, Ultra-processed foods.

<sup>a</sup> According to the World Health Organization Growth Reference for children ages 0-5 years, 2006.

<sup>b</sup> Variation in n is due to missing data.

<sup>c</sup> From t-tests for dichotomous variables and ANOVA test for ordinal variables.

<sup>d</sup> According to the Institute of Medicine 2009.

<sup>e</sup> UPFs included industrialized yogurt, artificial fruit juice, soda, candies, cookies, packaged savory snacks, hotdogs and instant noodles, chocolate drinks, ice cream, jelly, cake, and industrialized soup.

**Table 2.** Crude and adjusted regression models for body mass index-for-age z-score (zBMI) at 2 years of age<sup>a</sup> in the MINA-Brazil birth cohort (n=743).

<b>Dependent variable</b>	<b>Excessive GWG<sup>b</sup></b>	<b>EBF &lt; 3m<sup>c</sup></b>	<b>BF &lt; 1y<sup>c</sup></b>
<b>Child zBMI</b>			
Crude difference (95% CI)	0.34 (0.18, 0.50)	0.06 (-0.10, 0.23)	0.24 (0.07, 0.40)
Adjusted difference (95% CI) <sup>d</sup>	0.24 (0.08, 0.41)	0.05 (-0.12, 0.21)	0.28 (0.12, 0.44)

Abbreviations: GWG, gestational weight gain; EBF, exclusive breastfeeding; BF, breast feeding; CI, confidence interval; m, months; y, year.

<sup>a</sup> According to the WHO Growth Reference for children ages 0-5 years (WHO 2006).

<sup>b</sup> According to the Institute of Medicine 2009. Not excessive GWG was considered the reference group.

<sup>c</sup> EBF  $\geq$  3m and BF  $\geq$  1y were considered the reference groups.

<sup>d</sup> Models were adjusted for maternal schooling, self-report skin color, wealth index, primiparity, pre-pregnancy BMI, antenatal care visits, and child sex; the relationship between BF practices and zBMI was also adjusted for GWG and birthweight. Covariates were included in the multiple linear regression models if they were associated with the zBMI in the crude analysis at  $P < 0.20$ .

Note: Complete case analyses (GWG, n = 729; EBF, n = 662; BF, n = 729). Totals differ due to missing values for covariates.