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# Prenatal factors associated with birth weight and length and current nutritional status of hospitalized children aged 4-24 months

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### Abstract

**The objective of the present study was to investigate the associations of prenatal factors with birth weight and length, as well as current nutritional status, of children hospitalized in southern Brazil. We conducted a cross-sectional study of 300 child-mother pairs. Children were between 4 and 24 months old. They were at the inpatient unit or pediatric emergency department of the Hospital de Clínicas de Porto Alegre. Anthropometric data were collected, and a questionnaire on gestational data was answered by the children's mothers. Maternal variables of interest were: prepregnancy body mass index (BMI), gestational weight gain, smoking and/or use of alcohol, use of illicit drugs, gestational diabetes and/or high blood pressure. Children's variables of interest were: sex, gestational age, birth weight (BW) and birth length (BL), and current anthropometric data [body mass index for age (BMI/A), height for age (H/A), and weight for age (W/A)]. The gestational weight gain and smoking were associated with BW. We also found that H/A was associated with BW and BL, W/A was associated with BW, and BMI/A was associated with BL. The gestational weight gain was associated with BL, diabetes was associated with BW and BL, and high blood pressure was associated with low height in the first two years of life. We concluded that prenatal factors may have an influence on both BW and BL, causing the birth of small and large for gestational age children, and thus affecting their growth rate during the first years of life.**

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Key words: *Fetal development. Birth weight. Nutritional status. Infant nutrition.*

**FACTORES PRENATALES ASOCIADOS CON PESO Y LONGITUD AL NACER Y ACTUAL ESTADO NUTRICIONAL DE LOS NIÑOS ENTRE 4 Y 24 MESES HOSPITALIZADOS**

### Resumen

**El objetivo de este estudio fue identificar las asociaciones de factores prenatales con el peso y la longitud al nacer y el estado nutricional actual de los niños hospitalizados en el sur de Brasil. Para ello se realizó un estudio transversal de 300 pares de madres y niños de entre 4 y 24 meses de edad, que estaban en la unidad de hospitalización o de emergencia pediátrica del Hospital de Clínicas de Porto Alegre. Se recogieron los datos antropométricos y se respondió a un cuestionario sobre los datos del embarazo. Variables maternas en estudio: IMC antes del embarazo, aumento de peso gestacional, fumar y/o beber alcohol, uso de drogas ilegales, la diabetes y/o hipertensión gestacional; y de los niños: el sexo, la edad gestacional, el peso (PN) y la longitud al nacer (LN), así como los datos antropométricos actuales (índice de masa corporal para la edad (IMC/E), altura para la edad (A/E) y peso para la edad (P/E). Para las asociaciones entre variables se utilizó la prueba de chi-cuadrado y exacta de Fisher; para las que demostraron p<0.20 se realizó regresión logística. En el análisis, el aumento de peso gestacional y el tabaquismo se asociaron con PN. También señaló que si A/E se asoció con PN y LN, P/E se asoció con el PN y el IMC/E con el LN. En el análisis multivariado, el aumento de peso gestacional se asoció con LN, diabetes con PN y CN, y la hipertensión con el retraso del crecimiento en los dos primeros años de vida. Llegamos a la conclusión de que los factores prenatales pueden afectar tanto al peso como a la LN, provocando el nacimiento de niños pequeños o grandes para la edad gestacional, lo que afecta el crecimiento de estos en los dos primeros años de vida.**

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Palabras clave: *Desarrollo fetal. Peso al nacer. Estado nutricional. Nutrición del lactante.*

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## Abbreviations

BMI: Body Mass Index.
BMI/A: Body Mass Index for Age.
H/A: Height for Age.
W/A: Weight for Age.
BW: Birth Weight.
BL: Birth Length.
IOM: Institute of Medicine.
WHO: World Health Organization.
OR: Odds ratio.
CI: Confidence Intervals.

## Introduction

The eating habits of the Brazilian population have been changing in recent decades because of the increased consumption of junk food and reduced consumption of legumes, vegetables, and fruits[1]. In addition, junk food has been offered to children at an increasingly younger age[2]. These changes result in a nutritional transition process. That is, lower prevalence of nutritional deficits and higher prevalence of overweight and obesity[3] in increasingly younger age groups, with earlier onset of complications related to overweight, such as type 2 diabetes (DM2), high blood pressure and dyslipidemia[4].

Several studies have shown a strong association between low birth weight and development of chronic diseases in adulthood[5-6]. The predominant explanation for this association is Barker's hypothesis, also known as the thrifty phenotype hypothesis. Barker suggests that the fetus is able to adapt to adverse intrauterine environment, optimizing the use of reduced energy supplies to ensure survival. However, this adaptive process may lead to the metabolic benefit of certain organs at the expense of others. This causes persistent changes in tissue growth and function, thus contributing to an increased risk of chronic diseases in adulthood[5].

Maternal prepregnancy nutritional status or insufficient weight gain during pregnancy, as well as other risk factors, such as smoking, use of alcohol and drugs, height, parity, age, size of the placenta, and presence of maternal diseases (high blood pressure, diabetes), may interfere with intrauterine growth, leading to the birth of small-for-gestational-age children[7] and a greater chance of developing chronic diseases in adulthood[5].

However, most studies on factors affecting intrauterine growth have focused more on birth weight than on birth length. Nevertheless, current evidence shows that birth length is a strong predictor of future height and may be related to early death in adulthood[8]. Thus, the objective of the present study was to investigate the association of prenatal factors with birth weight and length, as well as current nutritional status, of children hospitalized at a teaching hospital in Porto Alegre, Rio Grande do Sul, Brazil.

## Methods

The present study is part of a larger cross-sectional study entitled "Maternal knowledge about feeding in the first years of life and its relationship to the introduction of complementary foods to children aged 4-24 months hospitalized at a tertiary hospital in Porto Alegre," conducted in Porto Alegre, Rio Grande do Sul, Brazil.

Our sample included female and male children whose mothers were with them at the hospital. Children's age ranged from 4 to 24 months and they were treated at the inpatient unit or emergency department of the Hospital de Clínicas de Porto Alegre between March 2012 and July 2013. Patients whose mothers were not present, who were using enteral and parenteral nutrition therapy, those with a chronic complication that could interfere with feeding and growth, such as neurological and genetic diseases, allergies, and/or food intolerances, were excluded from the study. In addition, we also excluded mothers younger than 18 years old who were not accompanied by their legal guardians, illiterate mothers, and those who were recommended not to breastfeed, such as HIV-positive mothers and those being treated for cancer.

The sample size was calculated based on another study conducted at a teaching hospital in São Paulo[9]. Using a 95% confidence interval, a margin of error of 5%, a statistical power of 80%, and considering that a weight gain during pregnancy $< 7$ kg is associated with prevalence of low birth weight newborns when compared with adequate weight gain during pregnancy (15.8 vs. 2.5%), we calculated a minimum of 300 mother-child pairs.

Resident nutritionists and undergraduate students of nutrition were trained to collect the anthropometric data and to administer the questionnaire related to the variables of interest. The variables related to prenatal care were: prepregnancy BMI, weight gain during pregnancy, smoking and/or drinking habits, use of illicit drugs, presence of diabetes or gestational diabetes, and chronic high blood pressure or preeclampsia. The variables related to the children were: sex, gestational age, birth weight and length, body mass index for age (BMI/A), height for age (H/A), and weight for age (W/A). Birth data were preferably collected from the children's health booklets.

The classification criteria suggested by Alexander et al. (1996)[10] were used for birth weight, and the criteria by Olsen et al. (2010)[11] was used for birth length considering children born at term. Preterm infants were evaluated and classified according to Fenton & Kim (2013)[12]. Considering both birth weight and length, those children who were below the 10th percentile were classified as small for gestational age (SGA), those between the 10th and 90th percentiles were classified as appropriate for gestational age (AGA), and those above the 90th percentile were considered large for gestational age (LGA).

Children's current nutritional status was assessed based on weight and length collected from their medical records. The curves for H/A, BMI/A, and W/A of the 2007 World Health Organization (WHO). Z-score was used considering the following cutoff points for BMI/A: < -2.00 standard deviation (SD) = underweight, ≥ -2.00 and < +2.00 SD = normal weight, and ≥ +2.00 SD = overweight. The cutoff points for H/A were: < -2.00 SD = short height and ≥ -2.00 SD = appropriate height for age. The cutoff points for W/A were: < -2.00 SD = underweight for age, ≥ -2.00 and < +2.00 SD = appropriate weight for age, and ≥ +2.00 SD = overweight for age. The cutoff points for W/A were: < -2.00 SD = underweight for age, between -2.00 and +2.00 SD = appropriate weight for age, and > +2.00 SD = overweight for age. Corrected age was used for the classification of preterm children.

Gestational weight gain, as well as the diagnosis of diabetes and hypertension were self-reported by mothers. In smoking, alcohol consumption and use of illicit drugs were considered only to the mother's statement as consumption during pregnancy, independent of dose and frequency. Maternal educational level was classified as up to 8 years of schooling, between 9 and 11 years of schooling, and over 12 years of schooling. Those mothers who had up to 8 years of schooling were considered to have a low educational level.

The weight reported by the mothers before pregnancy and the height measured on the day of data collection were used to calculate their prepregnancy BMI. The nutritional recommendations of the Institute of Medicine (2013)[13] for pregnant women were used to classify the prepregnancy BMI.

Gestational weight gain was evaluated according to the recommendation of the IOM (2013)[13] based on the prepregnancy nutritional status. For underweight pregnant women, a weight gain between 12.5 and 18.0 kg was considered adequate; for those with normal weight, a gain between 11.5 and 16.0 kg was considered appropriate; for overweight pregnant women, between 7.0 and 11.5 kg was an appropriate gain; and finally the obese women were expected to gain from 5.0 to 9.0 kg. Those values below the minimum recommended value were considered to be insufficient weight gain and the values above the recommended maximum value were considered to be excessive weight gain.

The statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 18.0. Univariate analysis was used to express the frequency of prenatal factors. The association of birth weight, birth length, and current nutritional status with prenatal variables was tested using Pearson's chi-square test or Fisher's exact test. Those variables showing a p-value < 0.20 in the univariate analysis were included in the multivariate analysis using logistic regression. The estimates were expressed as odds ratios (OR) and confidence intervals (CI). The level of significance was set at 0.05.

The present study was conducted according to the Guidelines and Regulatory Standards of Research Involving Humans Subjects (Resolution 196/96) and it was approved by the Research and Graduate Studies Group (GPPG) and Ethics Research Committee (CEP) of the Hospital de Clínicas de Porto Alegre (HCPA), protocol number 12-0080 (CEP-HCPA). Confidentiality of all participants' personal data was ensured.

## Results

Three-hundred and four mother-child pairs were included in the study. Four pairs were excluded because

**Table I**
*Characteristics of the sample and nutritional status of children between 4 and 24 months hospitalized at hospital in southern Brazil*

| *Variables* | *n* | *%* |
|---|---|---|
| **Sex** | | |
| Male | 178 | 59.3 |
| Female | 122 | 40.7 |
| **Gestational Age** | | |
| < 37 weeks | 48 | 16.0 |
| ≥ 37 weeks | 252 | 84.0 |
| **Birth weight** | | |
| SGA | 47 | 15.9 |
| AGA | 217 | 7 3.3 |
| LGA | 32 | 10.8 |
| **Birth length** | | |
| SGA | 85 | 28.9 |
| AGA | 198 | 67.3 |
| LGA | 11 | 3.7 |
| **BMI for age** | | |
| Underweight | 13 | 4.4 |
| Normal weight | 236 | 78.7 |
| Overweight | 51 | 17.0 |
| **Height for age** | | |
| Short height | 56 | 18.7 |
| Appropriate height | 244 | 81.3 |
| **Weight for age** | | |
| Underweight | 22 | 7.3 |
| Appropriate weight | 257 | 85.7 |
| Overweight | 21 | 7.0 |

SGA = small for gestational age; AGA = appropriate for gestational age; LGA = Large for gestational age; BMI = body mass index.

of incomplete data. Therefore, the final sample consisted of 300 mother-child pairs.

**Table II**
*Prenatal data and characteristics of mothers of children between 4 and 24 months hospitalized at hospital in southern Brazil*

| *Variables* | *n* | *%* |
|---|---|---|
| **Maternal age** | | |
| ≤ 19 years | 48 | 16.0 |
| 20-34 years | 221 | 73.7 |
| ≥ 35 years | 31 | 10.3 |
| **Maternal educational level** | | |
| ≤ 8 years | 124 | 41.5 |
| 9-11 years | 151 | 50.5 |
| ≥ 12 years | 24 | 8.0 |
| **Parity** | | |
| Primiparity | 111 | 37.0 |
| Multiparity | 189 | 63.0 |
| **Prepregnancy BMI** | | |
| Underweight (<18.5 kg/m$^2$) | 15 | 7.0 |
| Normal weight (18.5-24,9 kg/m$^2$) | 127 | 59.6 |
| Overweight (25-29.9 kg/m$^2$) | 50 | 23.5 |
| Obesity (>30 kg/m$^2$) | 21 | 9.9 |
| **Gestational weight gain** | | |
| Insufficient | 68 | 31.9 |
| Appropriate | 52 | 24.4 |
| Excessive | 93 | 43.7 |
| **Smokers** | | |
| Yes | 72 | 24.0 |
| No | 228 | 76.0 |
| **Drug use** | | |
| Yes | 4 | 1.3 |
| No | 296 | 98.7 |
| **Alcohol use** | | |
| Yes | 29 | 9.7 |
| No | 271 | 90.3 |
| **High blood pressure** | | |
| Yes | 52 | 17.3 |
| No | 248 | 82.7 |
| **Diabetes** | | |
| Yes | 13 | 4.4 |
| No | 285 | 95.6 |

BMI = body mass index.

Table I describes the children's characteristics. The sample consisted of mean age was 9.62 months (±5.07). The mother's characteristics are described in table II. Maternal age ranged from 16 to 45 years (mean 26.29 ± 08.06 years). Regarding diseases during pregnancy, 52 (17.3%) mothers had high blood pressure, and five of them (9.4%) were hypertensive before pregnancy; in addition, 13 (4.4%) mothers had diabetes, and two of them (15.4%) had type 1 diabetes before pregnancy.

In relation to the prenatal factors associated with anthropometric measures at birth (Table III), we found a statistically significant association between birth weight SGA with insufficient gestational weight gain and smoking, and excessive gestational weight gain with birth weight LGA. The univariate analysis showed that prepregnancy BMI and gestational weight gain were possibly associated with birth length and gestational diabetes, as well as birth weight and length. After performing the logistic regression, we found an association of gestational diabetes with birth weight (p = 0.04, OR = 0.27, 95% CI = 0.07-0.95) and an association of gestational weight gain (p = 0.04, and OR = 2.15, 95% CI = 1.004-4.62) and diabetes (p = 0.01, OR = 12.06, 95% CI = 0.006-0.55) with birth length. Thus, children of mothers who had insufficient weight gain during pregnancy have greater chance (OR = 2.15) of being SGA at birth when considering birth length. In addition, children born to mothers with gestational diabetes are more likely to be LGA at birth when considering both birth weight and length. When the anthropometric measures at birth are associated with the current nutritional status, we found that short H/A was associated both with birth weight and length SGA, whereas low W/A was associated with the birth of SGA infants, considering only the birth weight. Furthermore, it was observed that infants born SGA according birth length were overweight (BMI / I) within the first two years of life.

No statistically significant associations were found between children's prenatal factors and current nutritional status according to the univariate analysis (Table IV). However, after logistic regression, gestational high blood pressure was associated with H/A, demonstrating that children born to mothers with high blood pressure during pregnancy are four times more likely (OR = 5.46, 95% CI: 1.21-24.71) to have short height in the first two years of life, regardless of prepregnancy BMI and weight gain during pregnancy.

## Discussion

Birth weight is a strong predictor of perinatal mortality and morbidity[18] and development of chronic diseases in adulthood[5]. The global prevalence of low birth weight infants is 14%[14] and in southern Brazil is 13% of SGA newborns[15]. The prevalence of SGA infants in our study was approximately 16%, higher than the ra-

**Table III**
*Prenatal factors and current nutritional status associated with birth weight and length of children between 4 and 24 months hospitalized at hospital in southern Brazil*

| Variables | Birth Weight | | | | | | | Birth length | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | SGA | | AGA | | LGA | | | SGA | | AGA | | LGA | | |
| | n | % | n | % | n | % | $p^a$ | n | % | n | % | n | % | $p^a$ |
| **Maternal age** | | | | | | | 0.31 | | | | | | | 0.88 |
| ≤ 19 years | 12 | 25.5 | 29 | 13.4 | 6 | 18.8 | | 15 | 17.6 | 31 | 15.7 | 1 | 9.1 | |
| 20-34 years | 31 | 66.0 | 165 | 76.0 | 23 | 68.8 | | 61 | 71.8 | 147 | 74.2 | 8 | 72.7 | |
| ≥ 35 years | 4 | 8.5 | 23 | 10.6 | 4 | 12.5 | | 9 | 10.6 | 20 | 10.1 | 2 | 18.2 | |
| **Parity** | | | | | | | 0.63 | | | | | | | 0.30 |
| Primiparity | 16 | 34.0 | 84 | 38.7 | 10 | 31.3 | | 27 | 31.8 | 80 | 40.4 | 3 | 27.3 | |
| Multiparity | 31 | 66.0 | 133 | 61.3 | 22 | 68.8 | | 58 | 68.2 | 118 | 59.6 | 8 | 72.7 | |
| **Prepregnancy BMI** | | | | | | | 0.44 | | | | | | | 0.11[c] |
| Underweight | 4 | 11.1 | 11 | 7.1 | 0 | 0 | | 8 | 12.7 | 7 | 5.0 | 0 | 0 | |
| Appropriate | 22 | 61.1 | 90 | 58.1 | 14 | 70.0 | | 34 | 54.0 | 89 | 63.1 | 2 | 40.0 | |
| Overweight | 9 | 25.0 | 37 | 23.9 | 3 | 15.0 | | 17 | 27.0 | 31 | 22.0 | 1 | 20.0 | |
| Obesity | 1 | 2.8 | 17 | 11.0 | 3 | 15.0 | | 4 | 6.3 | 14 | 9.9 | 2 | 40.0 | |
| **Gestational weight gain** | | | | | | | 0.001[b] | | | | | | | 0.07[c] |
| Insufficient | **18** | **50.0** | 46 | 29.7 | 3 | 15.0 | | 27 | 42.9 | 37 | 26.2 | 2 | 40.0 | |
| Appropriate | 6 | 16.7 | 45 | 29.0 | 1 | 5.0 | | 11 | 17.5 | 41 | 29.1 | 0 | 0 | |
| Excessive | 12 | 33.3 | 64 | 41.3 | **16** | **80.0** | | 25 | 39.7 | 63 | 44.7 | 3 | 60.0 | |
| **Smokers** | | | | | | | 0.001[b] | | | | | | | 0.37 |
| Yes | **22** | **46.8** | 42 | 19.4 | 7 | 21.9 | | 25 | 29.4 | 44 | 22.2 | 2 | 18.2 | |
| No | 25 | 53.2 | 175 | 80.6 | 25 | 78.1 | | 60 | 70.6 | 154 | 77.8 | 9 | 81.8 | |
| **Drug use** | | | | | | | 0.74 | | | | | | | 1.00 |
| Yes | 1 | 2.1 | 2 | 0.9 | 1 | 3.1 | | 1 | 1.2 | 3 | 1.5 | 0 | 0 | |
| No | 46 | 97.9 | 215 | 99.1 | 31 | 96.9 | | 84 | 98.8 | 195 | 98.5 | 11 | 100 | |
| **Alcohol use** | | | | | | | 0.23 | | | | | | | 0.93 |
| Yes | 7 | 14.9 | 21 | 9.7 | 1 | 3.1 | | 9 | 10.6 | 19 | 9.6 | 1 | 9.1 | |
| No | 40 | 85.1 | 196 | 90.3 | 31 | 96.9 | | 76 | 89.4 | 177 | 90.4 | 10 | 90.9 | |
| **High blood pressure** | | | | | | | 0.55 | | | | | | | 0.46 |
| Yes | 6 | 12.8 | 39 | 18.0 | 7 | 21.9 | | 12 | 14.1 | 34 | 17.2 | 5 | 45.5 | |
| No | 41 | 87.2 | 178 | 82.0 | 25 | 78.1 | | 73 | 85.9 | 164 | 82.8 | 6 | 54.5 | |
| **Diabetes** | | | | | | | 0.07[c] | | | | | | | 0.07[c] |
| Yes | 1 | 2.1 | 8 | 3.7 | 4 | 12.5 | | 2 | 2.4 | 8 | 4.1 | 2 | 18.2 | |
| No | 46 | 97.9 | 207 | 96.3 | 28 | 87.5 | | 82 | 97.6 | 189 | 95.9 | 9 | 81.8 | |
| **BMI for age** | | | | | | | 0.70 | | | | | | | 0.04[b] |
| Underweight | 2 | 4.3 | 11 | 5.1 | 0 | 0 | | 6 | 7.1 | 6 | 3.0 | 1 | 9.1 | |
| Normal weight | 38 | 80.9 | 170 | 78.3 | 25 | 78.1 | | 59 | 69.4 | 163 | 82.3 | 10 | 90.9 | |
| Overweight | 7 | 14.9 | 36 | 16.6 | 7 | 21.9 | | **20** | **23.5** | 29 | 14.6 | 0 | 0 | |
| **Height for age** | | | | | | | 0.02[b] | | | | | | | 0.02[b] |
| Short height | **15** | **31.9** | 36 | 16.6 | 4 | 12.5 | | **24** | **28.2** | 30 | 15.2 | 1 | 9.1 | |
| Appropriate height | 32 | 68.1 | 181 | 83.4 | 28 | 87.5 | | 61 | 71.8 | 168 | 84.8 | 10 | 90.9 | |
| **Weight for age** | | | | | | | 0.02[b] | | | | | | | 0.07[c] |
| Underweight | **9** | **19.1** | 12 | 5.6 | 1 | 3.1 | | 12 | 14.2 | 10 | 5.0 | 0 | 0 | |
| Appropriate weight | 37 | 78.7 | 188 | 86.6 | 29 | 90.6 | | 66 | 77.6 | 176 | 88.9 | 10 | 90.9 | |
| Overweight | 1 | 2.1 | 17 | 7.8 | 2 | 6.3 | | 7 | 8.2 | 12 | 6.1 | 1 | 9.1 | |

[a]Chi-square test or Fisher's exact test. [b]Statistically significant association ($p<0.05$). [c]Association analyzed using logistic regression. BMI = body mass index; SGA = small for gestational age; AGA = appropriate for gestational age; LGA = large for gestational age.

**Table IV**
*Prenatal factors associated with the current nutritional status of children between 4 and 24 months hospitalized at hospital in southern Brazil*

| Variables | BMI for age | | | | | | | Height for age | | | | | Weight for age | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Underweight | | Normal weight | | Overweight | | | Low | | Appropriate | | | Underweight | | Appropriate weight | | Overweight | | |
| | n | % | n | % | n | % | $p^a$ | n | % | n | % | $p^a$ | n | % | n | % | n | % | $p^a$ |
| **Maternal age** | | | | | | | 0.43 | | | | | 0.50 | | | | | | | 0.16[b] |
| ≤ 19 years | 2 | 15.4 | 41 | 17.4 | 5 | 9.8 | | 10 | 17.9 | 38 | 15.6 | | 7 | 31.8 | 38 | 14.8 | 3 | 14.3 | |
| 20-34 years | 11 | 84.6 | 171 | 72.5 | 39 | 76.5 | | 38 | 67.9 | 183 | 75.0 | | 13 | 59.1 | 194 | 75.5 | 14 | 66.7 | |
| ≥ 35 years | 0 | 0 | 24 | 10.2 | 7 | 13.7 | | 8 | 14.3 | 23 | 9.4 | | 2 | 9.1 | 25 | 9.7 | 4 | 19.0 | |
| **Parity** | | | | | | | 0.34 | | | | | 0.32 | | | | | | | 0.27 |
| Primiparity | 3 | 23.1 | 92 | 39.0 | 16 | 31.4 | | 17 | 30.4 | 94 | 38.5 | | 9 | 40.9 | 91 | 35.4 | 11 | 52.4 | |
| Multiparity | 10 | 76.9 | 144 | 61.0 | 35 | 68.6 | | 39 | 69.6 | 150 | 61.5 | | 13 | 59.1 | 166 | 64.6 | 10 | 47.6 | |
| **Prepregnancy BMI** | | | | | | | 0.09[b] | | | | | 0.09[b] | | | | | | | 0.15[b] |
| Underweight | 2 | 20.0 | 9 | 5.5 | 4 | 10.5 | | 5 | 12.2 | 10 | 5.8 | | 4 | 21.1 | 9 | 5.1 | 2 | 11.8 | |
| Appropriate | 3 | 30.0 | 103 | 62.4 | 21 | 55.3 | | 19 | 46.3 | 108 | 62.8 | | 8 | 42.1 | 109 | 61.5 | 10 | 58.8 | |
| Overweight | 5 | 50.0 | 37 | 22.4 | 8 | 21.1 | | 14 | 34.1 | 36 | 20.9 | | 6 | 31.6 | 40 | 22.6 | 4 | 23.5 | |
| Obesity | 0 | 0 | 16 | 9.7 | 5 | 13.2 | | 3 | 7.3 | 18 | 10.5 | | 1 | 5.3 | 19 | 10.7 | 1 | 5.9 | |
| **Gestational weight gain** | | | | | | | 0.53 | | | | | 0.80 | | | | | | | 0.08[b] |
| Insufficient | 2 | 20.0 | 53 | 32.1 | 13 | 34.2 | | 15 | 36.6 | 53 | 30.8 | | 10 | 52.6 | 50 | 28.2 | 8 | 47.1 | |
| Appropriate | 2 | 20.0 | 44 | 26.7 | 6 | 15.8 | | 9 | 22.0 | 43 | 25.0 | | 2 | 10.5 | 48 | 27.1 | 2 | 11.8 | |
| Excessive | 6 | 60.0 | 68 | 41.2 | 19 | 50.0 | | 17 | 41.5 | 76 | 44.2 | | 7 | 36.8 | 79 | 44.6 | 7 | 41.2 | |
| **Smokers** | | | | | | | 0.25 | | | | | 0.28 | | | | | | | 0.27 |
| Yes | 1 | 7.7 | 56 | 23.7 | 15 | 29.4 | | 17 | 30.4 | 55 | 22.5 | | 6 | 27.3 | 58 | 22.6 | 8 | 61.9 | |
| No | 12 | 92.3 | 180 | 76.3 | 36 | 70.6 | | 39 | 69.6 | 189 | 77.5 | | 16 | 72.7 | 199 | 77.4 | 13 | 38.1 | |
| **Drug use** | | | | | | | 0.62 | | | | | 0.33 | | | | | | | 0.27 |
| Yes | 0 | 0 | 3 | 1.3 | 1 | 2.0 | | 0 | 0 | 4 | 1.6 | | 0 | 0 | 3 | 1.2 | 1 | 4.8 | |
| No | 13 | 100 | 233 | 98.7 | 50 | 98.0 | | 56 | 100 | 240 | 98.4 | | 22 | 100 | 254 | 98.8 | 20 | 95.0 | |
| **Alcohol use** | | | | | | | 0.53 | | | | | 0.33 | | | | | | | 0.09[b] |
| Yes | 0 | 0 | 23 | 9.7 | 6 | 11.8 | | 3 | 5.4 | 26 | 10.7 | | 0 | 0 | 25 | 90.3 | 4 | 19.0 | |
| No | 13 | 100 | 213 | 90.3 | 45 | 88.2 | | 53 | 94.6 | 218 | 89.3 | | 22 | 100 | 232 | 9.7 | 17 | 81.0 | |
| **High blood pressure** | | | | | | | 0.95 | | | | | 0.10[b] | | | | | | | 0.57 |
| Yes | 2 | 84.6 | 42 | 17.8 | 8 | 15.7 | | 5 | 8.9 | 47 | 19.3 | | 2 | 9.1 | 46 | 17.9 | 4 | 19.0 | |
| No | 11 | 15.4 | 194 | 82.2 | 43 | 84.3 | | 51 | 91.1 | 197 | 80.7 | | 20 | 90.9 | 211 | 82.1 | 17 | 81.0 | |
| **Diabetes** | | | | | | | 0.24 | | | | | 0.96 | | | | | | | 0.55 |
| Yes | 0 | 0 | 13 | 5.5 | 0 | 0 | | 3 | 5.4 | 10 | 4.1 | | 0 | 0 | 13 | 5.1 | 0 | 0 | |
| No | 12 | 100 | 222 | 94.5 | 51 | 100 | | 53 | 94.6 | 232 | 95.9 | | 22 | 100 | 242 | 94.9 | 21 | 100 | |

[a]Chi-square test or Fisher's exact test. [b]Association analyzed using logistic regression. BMI = body mass index.

tes found in other studies, possibly because our sample included only hospitalized children.

In present study, the prevalence of women who smoked during pregnancy was 24%, showing a statistically significant association with SGA infants according to birth weight. In agreement with these findings, regional study found similar prevalence[15]. It is known that the risk factors for low birth weight, maternal smoking is one of the most important modifiable factors[16], since tobacco use during pregnancy is an independent determinant of infant mortality and is associated with reduced birth weight[15,17] and birth length[15]. The mechanisms involved with the effects of maternal smoking during pregnancy on intrauterine fetal growth are not yet fully understood. However, there is evidence that smoking during pregnancy may be associated with higher blood pressure, cardiovascular diseases, altered lipid profile, and weight gain from childhood to adulthood. Nicotine is a teratogen that can induce vasoconstriction in the uterus and placenta, thus reducing blood flow and supply of oxygen and nutrients to the fetus, affecting growth and development[16].

Insufficient gestational weight gain was also associated with SGA babies, considering both weight and length at birth (OR=2.15, CI=1.00-4.62). A recent study showed that low prepregnancy BMI, an independent and combined effect with weight gain during pregnancy, was associated with SGA infants;[18] in addition, the authors found that there was a 2.23 higher chance of infant mortality, regardless of gestational age, low birth weight, maternal age, maternal educational level, and maternal race[19]. These findings corroborate the theory of Barker (1995), which suggests that a limited intrauterine environment, both due to maternal malnutrition and insufficient weight gain during pregnancy, induces the fetus to adapt to malnutrition by means of metabolic changes, redistribution of blood flow, and changes in the production of fetal and placental hormones that control growth, resulting in slow growth, associating so low birth weight to development of chronic diseases in adulthood[5]. Current evidence also suggests that birth length is associated with an increase of 1.63cm in height at age 11, regardless of birth weight, thus demonstrating that birth length is a strong predictor of future height[8].

Although our study has also found no association between prepregnancy maternal obesity and birth weight and length and current nutritional status of infants, we found that excessive weight gain during pregnancy may be associated with LGA infants considering birth weight. The percentage of mothers with excessive weight gain during pregnancy was 43.7%, and 33.4% of mothers were overweight or obese before pregnancy. Corroborating our findings, Brazilian study found high prevalence of women with excessive weight gain during pregnancy and overweight and obesity in early pregnancy[20]. Excessive weight gain during pregnancy in mothers with normal prepregnancy BMI was also associated with increased birth weight and incidence of fetal macrosomia[21], in addition to overweight and increased adiposity at age five, controlling for socioeconomic factors, family lifestyle, birth weight for gestational age, and breastfeeding[22]. These figures are a reason for concern because obesity in women of childbearing age and during pregnancy has been increasing over the last 20 years[23]. Furthermore, obesity during pregnancy may result in adverse effects for both mother, such as increased mortality, preeclampsia and gestational diabetes, and the baby, such as being LGA at birth and higher risk of developing chronic diseases throughout life[24].

Gestational diabetes was associated with the birth of LGA infants classified according to birth weight and length. The association of gestational diabetes with excessive birth weight is already well established in the literature. In agreement with these findings, a study conducted in Rio Grande do Sul involving 7,760 children also found this association[25]. However, our findings suggest that gestational diabetes is associated with longer birth length, although we could not find studies in the literature evaluating this association. In addition, recent evidence suggests that prenatal exposure to diabetes accelerates the increase in BMI in late childhood (between 10 and 13 years), regardless of socioeconomic factors and prepregnancy BMI[26].

In terms of current nutritional status, we found the following associations: birth weight (SGA) and low weight for age (W/A), birth weight and length (SGA) and short height for age (H/A), and birth length (SGA) and overweight in the first two years of life. A study conducted in Pelotas (RS), Brazil, also found a higher percentage of children with short H/A and low W/A at the end of the first year of life among low birth weight children[27]. Approximately 10% of SGA children remain below two standard deviations of height during childhood, adolescence, and adulthood. Although more than 80% of them catch up growth during the first six months of life and most of them reach above two standard deviations height at age 2. However, SGA preterm babies may take longer to catch up than babies born at term[7].

Recently, short height gained international attention when, in May 2012, the World Health Organization (WHO) adopted a resolution on maternal-infant health and nutrition that included six global goals to reduce the high rate of diseases associated with malnutrition, particularly during the critical period from conception to 24 months of age. The first goal is related to short height and it aims to reduce by 40% the number of children with short height under 5 years old by 2025. This problem affects a large numbers of children worldwide and brings consequences for health in the long term, including cognition and learning deficits, loss of productivity and, when there is also excessive weight gain during childhood, increased risk of chronic diseases[28]. It is estimated that about 20% of a 10 cm height deficit at 3 years old is already present at birth[29]. In addition, a cohort study from Pelotas (RS), Brazil, showed a mean difference of 3 cm in the height of 2,106 boys and

1,947 girls in the first four years of life between extreme categories of maternal educational level, which represents 2.9% of the mean height of those children from mothers with higher educational level. This difference was observed since birth and it increased in the first two years of life[30]. This evidence may explain the high prevalence of short height (18.7%) found in our study, as 15.9% and 28.9% were classified as SGA according to birth weight and length, respectively, and because it is a maternal sample where nearly half of the mothers had low educational level (41.5%).

Despite the nutritional risk of SGA children in the first years of life, special attention is needed, since low birth weight *per se* is not responsible for the increased risk of developing diseases later in adulthood; instead fast catch-up growth after birth may prompt the development of diseases[31]. New evidence suggests that SGA children whose growth rate is higher during the first years of life have a greater chance of obesity later in childhood[32], which is in agreement with our findings, since those children who were born SGA considering their length were overweight in the first years of life. In particular, low birth weight babies are highly likely to be overfed, leading to rapid weight gain, which is positively related to overweight in adulthood. A study conducted in India showed that over 70% of mothers added complementary foods to the diet of infants at six weeks of age and 80% did so to the diet of infants atfour months of age because they believed that their babies "were not growing enough" with exclusive breastfeeding[33]. Also, traditionally, in many societies and cultures, "chubby" babies are considered to be healthy. This deeply rooted belief leads mothers to make all possible efforts to improve weight gain in early postnatal life[34].

Another association with current nutritional status found in our study was that high blood pressure during pregnancy is a risk factor for short height. A study conducted in the same hospital comparing preterm very low birth weight infants from mothers with preeclampsia with controls found that those children born to mothers with preeclampsia did not show the catch-up weight gain in the first 18 months of corrected age[35]. This finding could explain this possible association, since high blood pressure during pregnancy is associated with SGA newborns;[7] and in the present study we found a prevalence of 12.8% and 14.1% of SGA children according to birth weight and length, respectively, from mothers with high blood pressure.

However, it is worth considering some limitations of the present study: cross-sectional design; sample size, since variables such as prepregnancy BMI, BMI/A, and W/A showed possible trend of association with birth length in the univariate analysis, however we could not analyze this in the multivariate analysis because of lack of children within each category. This was also true regarding the association between W/A and alcohol consumption during pregnancy, possibly because some mothers did not report alcohol intake as its consumption is not recommended during pregnancy. Furthermore, recall bias must be considered because maternal variables such as weight before pregnancy and gestational weight gain were mostly reported by mothers. Nevertheless, it is worth noting that the heterogeneity of the sample makes it possible to extrapolate our data to other individuals in the same age group. It is also noteworthy that data collection was conducted by a trained research team and we used instruments and techniques that have been validated internationally and nationally.

Thus, we conclude that prenatal factors such as insufficient gestational weight gain and smoking are risk factors for the birth of SGA children considering birth weight and/or length, and these children have low weight and height for age and are overweight (BMI/A) in the first two years of life. Conversely, excessive weight gain during pregnancy and gestational diabetes were considered risk factors for the birth of LGA children considering birth weight and/or length. In addition, high blood pressure during pregnancy was shown to be a risk factor for short height in the first two years of life.

Therefore, it is important to highlight that not only birth weight, but also birth length is influenced by the intrauterine environment and can be a predictor for the development of chronic diseases in adulthood. Thus, cohort studies investigating birth length are needed to identify this long-term influence. Furthermore, during the prenatal period, it is important to detect the risk factors for the birth of children with inappropriate weight and length for gestational age (SGA and LGA). We expect that such knowledge makes it possible to plan prenatal care that effectively includes actions to reduce the nutritional inadequacies during pregnancy and to prevent the development of chronic diseases in adulthood.


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## Conflict of interests

The authors have no conflict of interest to declare.

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