The influence of the Municipal Human Development Index compared to maternal education on infant mortality: a retrospective cohort study in the extreme south of Brazil

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Abstract

**Background:** Infant mortality is considered an important and sensitive health indicator in several countries, especially in underdeveloped and developing countries. Most of the factors influencing infant mortality are interrelated and are the result of social issues. Thus, this study investigated the influence of the Municipal Human Development Index (MHDI) of the residence macro-region compared to maternal education on infant mortality in a capital city in the extreme south of Brazil.

**Methods:** It is a retrospective cohort study with data on births and deaths for the period of 2000-2017. The association between the independent variables and the outcome was done by bivariate analysis through simple Poisson regression. Those with significant association (p<0.001) were used in a multiple Poisson regression for robust variances - adjusted model.

**Results:** The study included 311361 children, of whom 2271 died. Maternal education, individually and jointly analyzed with the MHDI, showed association with the outcome of infant death in the first year of life, particularly for children of mothers with lower maternal education (p<0.001). In relation to other related factors, maternal age; number of Prenatal Care Consultations; gestational age, weight, gender and Apgar Index (5th minute) of the newborn showed association with IM (p<0.001).

**Conclusions:** The lower the HDI classification of the macro-region, the worse were the socioeconomic and demographic conditions, but the results presumably indicated that an individual maternal characteristic supplants the environment in which the family resides as a factor of protection to infant mortality, reinforcing the relevance of maternal education as a social determinant in health.

1. Background

Infant mortality (IM) is considered, internationally, as one of the most sensitive health indicators, since it is related to social conditions and can also be influenced by prenatal and perinatal factors, as well as environmental factors, especially nutritional and infectious ones [1-3]. Worldwide, countries have dedicated themselves to achieving Millennium Development Goal 4 (MDG 4), which was to reduce by two-thirds the mortality of children under five by the year of 2015. Currently, efforts are focused on the new agenda in which Millennium Development Goal 3 (MDG 3) keeps the reduction of under-five mortality to at least 25 per 1,000 live births as a priority[4].

In Brazil there was a significant reduction in IM in the period from 1990 to 2012, when MDG 4 was achieved three years before the deadline [5, 6]. However, as in other countries, neonatal deaths still remained high and corresponded to approximately 70% of mortality in the first year of life [1, 7]. Porto Alegre, the state capital located in the extreme south of Brazil and where the present study was carried out, presented a variation in the infant mortality rate from 18.22 in 1994 to 9.13 deaths per thousand live births in 2018, which represented a decrease of 49.89% [8]. For the epidemiological surveillance of such vital events, in Brazil, the Live Births Information System (SINASC) and the Mortality Information System (SIM) are used [9].

Most of the factors influencing IM are interrelated and are the result of social issues, including the educational level of the mother, which is an important social determinant for better child health conditions because it leads to a better maternal perception of health needs and problems. Maternal education seems to be directly related to the healthy growth and development of the child [10, 11]. The region of residence is also related, albeit indirectly, to IM, being an important social factor in child health outcomes [12], as less developed regions may have worse physical structure and sanitation conditions and limited access to health services [3, 13, 14].

There are important differences in these factors between countries, especially in developing countries like Brazil, where there are differences between regions according to socio-economic characteristics, with significant social inequities. As an alternative to assess these development disparities in different countries, the Human
Development Index (HDI) evaluates human development through three indicators: schooling (expected years of schooling for children of school age and average schooling in years for adults over 25), longevity (life expectancy at birth) and income (per capita income). In this context, the Municipal Human Development Index (MHDI) was launched in Brazil in 2013. It was a strategy to adapt the HDI to the local context, allowing the calculation of HDI at the municipal level of the metropolitan regions of Brazil. MHDI considers the same three dimensions of Global HDI (longevity, education and income), including its three components, MHDI Income (MHDII), MHDI Longevity (MHDIL), MHDI Education (MHDIE), but it is adapted to the national context and uses local indicators available for the calculation [15]. The general MHDI of Porto Alegre was 0.805 in 2010, ranking as the 7th best Brazilian capital[15].

Because it is a sensitive indicator for socioeconomic and environmental changes, IM should be constantly monitored, and a better understanding of the association of HDI and maternal education with IM assists in the planning of actions and policies aimed at maternal and child health, particularly in regions of greater social vulnerability [1, 3]. Therefore, this study investigated the influence of the MHDI of the residence macro-region compared to the maternal education on infant mortality in a capital city in the extreme south of Brazil.

## 2. Methods

This is a retrospective cohort study that used the annual SIM and SINASC databases provided by the Non transmissible Vital Events, Diseases and Aggravates Surveillance Team of the General Health Surveillance Coordination of the Porto Alegre Municipal Health Secretariat.

The city of Porto Alegre has an estimated population of 1,479,101 people and has 17 macro-regions, each of which is made up of a set of neighborhoods with affinities to each other [8], it has an area of 471.85km². In relation to education level, in 2017, the illiteracy rate was 2.27%, the Basic Education Development Index (IDEB) was 4.9 (target 5.5) for the initial years and 3.9 (target 4.7) for the final years. Regarding mothers heads of families from 2000 to 2010, the percentage of women without complete elementary education improved by 26.89%, from 39.87–29.15% [8].

The study included all live births from 2000 to 2016 obtained from SINASC and all deaths of children under one year of age from 2000 to 2017 obtained from SIM in the municipality of Porto Alegre. The following newborns were excluded: twins or in higher numbers to avoid double maternal data; with birth weight of less than 500 grams, usually excluded in studies investigating infant mortality; with congenital anomalies or malformations, because they are not considered avoidable factors and children who were not born in the municipality of Porto Alegre. The decision to exclude newborns with congenital anomalies was made after the significant association of these, alone, with death in the first year of life (p < 0.001), through the Chi-square test. Although there may have been double entry of mothers due to the effect of the long period analyzed, it was considered that, eventually, they may have changed homes and also improved their level of education. In addition, the study population is based on the newborn that will become a new case even if it is a second child of a given mother.

From SINASC, the following variables were used: number of Declaration of Live Birth; maternal age (10-17; 18–34; ≥35 years); maternal education in completed years of study (< 8; 8–11; ≥12 years); maternal home district (ANNEX I) [16]; Planning Management Region of Maternal Residence; Participatory budgeting Regions of Maternal Residence, which were later called macro-regions (ANNEX II and ANNEX III) [16]; maternal marital status (married/ stable union, single/separated/widowed); number of previous living children; number of previous dead children (none; ≥1); number of Prenatal Care Consultations (None; 1–3; 4–6; ≥7); gestational age in weeks (< 27, 28–31, 32–36, ≥ 37); type of hospital (public, private, mixed); type of delivery (vaginal, cesarean); weight of the newborn (grams); Apgar rate at the 5th minute of life (≥ 7, < 7); gender of the newborn (female, male). From SIM, the variables used were: the number of the Declaration of Live Birth and date of death. The following variables were also introduced in the bank: year; parity, created from the number of live children and number of dead children (primipara, multipara) and the value of the MHDI of the macro-regions of maternal domicile and its three components: MHDI Income (MHDII), MHDI Longevity (MHDIL) and MHDI Education (MHDIE). These were later classified as very low (0-0.499), low (0.5-0.599), medium (0.6-0.699), high (0.7-0.799) and very high (0.8-
1.0), according to the classification used by the online platform Atlas of Human Development in Brazil [15]. The MHDI values were calculated based on the 2010 Brazilian Institute of Geography and Statistics (IBGE) Demographic Census. In the studied city, no macro-region has the MHDI less than 0.6. Thus, the MHDI was classified only as medium, high and very high. The exception was only for the MHDIE component which still has the low MHDI classification.

Subsequently, a linkage was made between the two databases through the number of the Declaration of Live Birth (DLB), the name of the mother and the date of birth. After a first automatic attempt, there was no agreement on the number of DLB of 269 children who died in the first year of life (7.2% of total deaths) between the two databases. From then on, a manual search was carried out in an attempt to correct and locate the number of the DLB, through the name of the mother, which was confirmed by the date of birth and weight of the newborn and, in a few cases, the address of the maternal residence. From this process, a further 165 deaths were located (4.4% of the total deaths of children in the first year) and the DLB numbers were corrected according to the SINASC database, totaling a final loss of 104 children (2.8% of the total deaths).

Preliminarily, a descriptive analysis of variables with absolute and relative frequencies was presented. The association of the macro-region and the other variables of the study with the death outcome was performed by Chi-square test. Later, the association between the determinants involved (independent variables) with the outcome of death was verified by a bivariate analysis through simple Poisson regression. Finally, the variables that showed statistically significant association (p < 0.001), as well as maternal education, were used in a model adjusted to estimate the influence of MHDI, MHDII, MHDIL and MHDIE on infant mortality in a multiple Poisson regression for robust variances.

The study was approved by the Research Ethics Committees of Hospital de Clínicas of Porto Alegre and the Research Ethics Committees of Municipal Health Department of Porto Alegre, respectively, under the respective protocol numbers 2,940,235 and 3,153,671.

3. Results

311,361 children were included in the study. Of these 2271 died in the first year of life (Fig. 1).

The majority of mothers were between 18 and 34 years old, 64.1% (n = 199,120) of them were single, legally separated or widowed and the minority, 44.9% (n = 139,607) were primiparas which proved to be a protective factor for infant mortality. Regarding prenatal care, 31.8% (n = 98,835) had less than seven consultations, which proved to be a risk factor for infant death in the first year of life. Vaginal delivery occurred in 53.6% (n = 9,166,865) of births and most of them in mixed or private hospitals (53.2%). Newborns with a gestational age of less than 37 weeks, an Apgar Index of less than 7 at the fifth minute of life and low weight were also considered risk factors for death (p < 0.001). All variables presented significant association with death in the preliminary gross analysis (Table 1), but in the consecutive multivariate analysis, maternal age, previous number of dead children and type of delivery were not associated with the infant mortality outcome.
Table 1
Planning Management Regions and Participatory budgeting Regions (macro-regions) and their corresponding MHDI values and their 3 components of the studied city (Porto Alegre, RS, Brazil).

| Planning Management Regions | MACRO-REGION                  | MHDI 2010 | MHDII 2010 | MHDIL 2010 | MHDIE 2010 |
|-----------------------------|--------------------------------|-----------|------------|------------|------------|
| Center                      | Center                         | 0.935     | 0.984      | 0.929      | 0.894      |
| Humaitá/ Navegantes/ Islands and Northwest | Humaitá / Navegantes | 0.765     | 0.807      | 0.854      | 0.649      |
|                            | Northwest                      | 0.89      | 0.921      | 0.913      | 0.837      |
|                            | Islands                        | 0.659     | 0.705      | 0.805      | 0.504      |
| North and eixo Baltazar     | North                          | 0.729     | 0.75       | 0.833      | 0.62       |
|                            | Eixo Baltazar                  | 0.779     | 0.785      | 0.849      | 0.709      |
| East/Northeast              | East                           | 0.777     | 0.831      | 0.874      | 0.646      |
|                            | Northeast                      | 0.638     | 0.655      | 0.778      | 0.509      |
| Glória/ Cruzeiro and Cristal | Cristal                        | 0.809     | 0.858      | 0.887      | 0.695      |
|                            | Cruzeiro                       | 0.747     | 0.797      | 0.851      | 0.614      |
|                            | Glória                         | 0.733     | 0.775      | 0.841      | 0.605      |
| Center-South and South      | Center-South                   | 0.797     | 0.817      | 0.868      | 0.713      |
|                            | South                          | 0.843     | 0.897      | 0.892      | 0.75       |
| Lomba do Pinheiro/ Partenon | Lomba do Pinheiro              | 0.683     | 0.691      | 0.806      | 0.571      |
|                            | Partenon                       | 0.764     | 0.795      | 0.851      | 0.659      |
| Restinga/ Far South         | Restinga                       | 0.685     | 0.705      | 0.803      | 0.567      |
|                            | Far South                      | 0.714     | 0.756      | 0.835      | 0.576      |

RS: Rio Grande do Sul. MHDI: Municipal Human Development Index; MHDII: Income component of the Municipal Human Development Index; MHDIL: Longevity component of the Municipal Human Development Index; MHDIE: Education component of the Municipal Human Development Index.

Source: OBSERVAPOA and PROCEMPA, 2016.
Table 1
Distribution of absolute frequency and association of socio-demographic, perinatal and neonatal characteristics on Infant Mortality in Porto Alegre from 2000 to 2017.

| Maternal Age | TOTAL n(%) | DEATH n(%) | RR[CI95%] | Value of p |
|--------------|------------|------------|-----------|------------|
| 10 to 17 years | 24264 (7.8) | 23969 (98.8) | 295 (1.2) | 1.72[1.52–1.95] | < 0.001 |
| ≥ 35 years | 51883 (16.7) | 51569 (99.4) | 314 (0.6) | 0.86[0.76–0.97] | 0.012 |
| 18 to 34 years | 235210 (75.5) | 233550 (99.3) | 1,660 (0.7) | 1 | |

| Marital Status | TOTAL n(%) | DEATH n(%) | RR[CI95%] | Value of p |
|----------------|------------|------------|-----------|------------|
| Single/Separated/Widowed | 199120 (64.1) | 197362 (99.1) | 1,758 (0.9) | 1.95[1.77–2.15] | < 0.001 |
| Married/stable union | 111512 (35.9) | 111007 (99.5) | 505 (0.5) | 1 | |

| Parity | TOTAL n(%) | DEATH n(%) | RR[CI95%] | Value of p |
|--------|------------|------------|-----------|------------|
| Primipara | 139607 (44.9) | 138735 (99.4) | 872 (0.6) | 0.77[0.71–0.84] | < 0.001 |
| Multipara | 171217 (55.1) | 169825 (99.2) | 1392 (0.8) | 1 | |

| Number of dead children | TOTAL n(%) | DEATH n(%) | RR[CI95%] | Value of p |
|-------------------------|------------|------------|-----------|------------|
| ≥ 1 | 29794 (9.6) | 29516 (99.1) | 278 (0.9) | 1.32[1.16–1.49] | < 0.001 |
| None | 281491 (90.4) | 279500 (99.3) | 1991 (0.7) | 1 | |

| Number of | TOTAL n(%) | DEATH n(%) | RR[CI95%] | Value of p |
|-----------|------------|------------|-----------|------------|
| | | | | | |
| Prenatal Care Consultations | NO n(%) | YES n(%) | DEATH | RR[CI95%] | Value of p |
|-----------------------------|---------|----------|-------|-----------|-----------|
| None                        | 9444 (3.0) | 9044 (95.8) | 400 (4.2) | 14.04[12.41-15.89] | < 0.001 |
| From 1 to 3                 | 25084 (8.1) | 24514 (97.7) | 570 (2.3) | 7.53[6.73-8.43] | < 0.001 |
| From 4 to 6                 | 64307 (20.7) | 63666 (99.0) | 641 (1.0) | 3.30[2.96-3.69] | < 0.001 |
| 7 and more                  | 211538 (68.2) | 210900 (99.7) | 638 (0.3) | 1 | |
| **Birth**                   |         |          |       |           |           |
| Vaginal                     | 166865 (53.6) | 165508 (99.2) | 1357 (0.8) | 1.29[1.18-1.4] | < 0.001 |
| Cesarean                    | 144493 (46.4) | 143579 (99.4) | 914 (0.6) | 1 | |
| **Gestational Age**         |         |          |       |           |           |
| Less than 27 weeks          | 1228 (0.4) | 549 (44.7) | 679 (55.3) | 173.29[159.58-188.17] | < 0.001 |
| 28 to 31 weeks              | 2502 (0.8) | 2181 (87.2) | 321 (12.8) | 40.21[35.62-45.39] | < 0.001 |
| 32 to 36 weeks              | 25315 (8.1) | 24991 (98.7) | 324 (1.3) | 4.01[3.53-4.55] | < 0.001 |
| 37 weeks or more            | 281745 (90.7) | 280846 (99.7) | 899 (0.3) | 1 | |
| **TOTAL n(%)**              |         |          |       |           |           |
| NO                          | 306486 | 305009 | 1477 (0.5) | 1 | |
| YES                         |         |          |       |           |           |
| Apgar at 5 minutes          |         |          |       |           |           |
| < 7                         | 3198 (1.0) | 2538 (79.4) | 660 (20.6) | 42.82[39.34-46.62] | < 0.001 |
| 7                           |         |          |       | 1 | |
The proportion of mothers aged 35 years or older increases according to the MHDI classification, being higher (25.2%) in those residing in macro-regions with very high MHDI. Independent of the MHDI classification, a maternal age under 18 years showed association with child death in the first year of life ($p < 0.05$). In macro-regions with high and very high MHDI, single mothers, judicially separated or widowed, multiparas and with one or more previous dead children also showed association with death ($p < 0.05$). Regardless of the MHDI classification, the lower the number of Prenatal Care Consultations the higher the percentage of deaths. The percentage of cesarean sections was higher in macro-regions with high and very high MHDI (43% and 60.6%, respectively) and in these two classifications, vaginal delivery showed significant association with death. In the three classifications of MHDI (medium, high and very high), the proportion of deaths was higher for those newborns with a lower gestational age, with low weight or with an Apgar Index of less than 7 at the fifth minute of life. The public hospital showed a significant association with death, regardless of the MHDI classification (Table 2).

### Table 2

Distribution of the absolute frequency of sociodemographic, perinatal and neonatal characteristics according to the MHDI classification in Porto Alegre from 2000 to 2017.

| MHDI | |
|------|-----------|
| ≥ 7  | (99.0)    | (99.5)    |
|      | Low Weigh | No (≥2500 | 285625  (91.7) | 284723  (99.7) | 902 (0.3) | 0.59[0.05–0.06] | < 0.001 |
|      | Yes (<2500 | 25736  (8.3) | 24367  (94.7) | 1369 (5.3) | 1         | |
|      | Weight     |          |          |          |          |          |          |
|      | Newborn    | Female   | 152197  (48.9) | 151158  (99.3) | 1039 (0.7) | 0.88[0.81–0.96] | 0.003 |
|      | Sex        | Male     | 159164  (51.1) | 157932  (99.2) | 1232 (0.8) | 1         | |
|      |            |          |          |          |          |          |          |
|      | Type of    | Public   | 143615  (46.3) | 142,287 (99.1) | 1328 (0.9) | 3.64[3.15–4.21] | < 0.001 |
|      | Hospital   | Mixed    | 83982  (27.1) | 83280  (99.2) | 702 (0.8) | 3.29[2.82–3.84] | < 0.001 |
|      |            | Private  | 82781  (26.7) | 82571  (99.7) | 210 (0.3) | 1         | |

**Dependent variable:** death. **RR:** relative risk. **CI95%:** 95% confidence interval. **n:** number of participants. **%:** percentage. **<:** less.
| Maternal Age | TOTAL | DEATH | TOTAL | DEATH | TOTAL | DEATH |
|--------------|-------|-------|-------|-------|-------|-------|
| 10 to 17 years | 5385 (10.6) | 71 (1.3)* | 15341 (8.6) | 171 (1.1)* | 3532 (4.3) | 53 (1.5)* |
| 18 to 34 years | 39570 (77.7) | 326 (0.8) | 138025 (77.3) | 1020 (0.7) | 57537 (70.5) | 313 (0.5) |
| ≥ 35 years | 6002 (11.8) | 52 (0.9) | 25268 (14.1) | 171 (0.7) | 20598 (25.2) | 90 (0.4) |
| Maternal Education | | | | | | |
| < 8 years | 19791 (39.0) | 229 (1.2)* | 57655 (32.4) | 686 (1.2)* | 13,071 (16.1) | 157 (1.2)* |
| ≥ 8 to 11 years | 24486 (48.3) | 183 (0.7) | 82070 (46.1) | 524 (0.6) | 25,040 (30.8) | 162 (0.6)* |
| ≥ 12 years | 6406 (12.6) | 32 (0.5) | 38240 (21.5) | 149 (0.4) | 43,311 (53.2) | 135 (0.3) |
| Marital Status | | | | | | |
| Single/Seperated/Widowed | 36183 (71.2) | 343 (0.9) | 120594 (67.7) | 1079 (0.9)* | 42288 (51.9) | 334 (0.8)* |
| Married/stable union | 14619 (28.8) | 105 (0.7) | 57643 (32.3) | 281 (0.5) | 39206 (48.1) | 119 (0.3) |
| Parity | | | | | | |

50957 (100) | 178634 (100) | 81667 (100)
|                        | Primipara | Multipara | Primipara | Multipara | Primipara | Multipara |
|------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Number of Dead Children|           |           |           |           |           |           |
| ≥ 1                    | 4912 (9.6)| 46 (0.9)  | 16988 (9.5)| 166 (1.0)*| 7887 (9.7)| 64 (0.8)* |
| None                   | 46030 (90.4)| 404 (0.9)| 161604 (90.5)| 1195 (0.7)| 73763 (90.3)| 391 (0.5) |

| MHDI                   | MEDIUM n(%)| HIGH n(%)| VERY HIGH n(%)| MEDIUM n(%)| HIGH n(%)| VERY HIGH n(%)| MEDIUM n(%)| HIGH n(%)| VERY HIGH n(%)| MEDIUM n(%)| HIGH n(%)| VERY HIGH n(%)| MEDIUM n(%)| HIGH n(%)| VERY HIGH n(%)|
| Number of Dead Children| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH| TOTAL DEATH|
|                        |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| None                   | 1801 (3.6)| 71 (3.9)*| 5868 (3.3)| 246 (4.2)*| 1762 (2.2)| 82 (4.7)*|
| from 1 to 3           | 5381 (10.6)| 115 (2.1)*| 15530 (8.7)| 364 (2.3)*| 4166 (5.1)| 90 (2.2)*|
| from 4 to 6           | 13128 (25.9)| 137 (1.0)*| 39575 (22.2)| 381 (1.0)*| 11581 (14.2)| 123 (1.1)*|
| 7 and more            | 30368 (59.9)| 121 (0.4)| 117139 (65.8)| 360 (0.3)| 63974 (78.5)| 157 (0.2)|
|                        | 50678 (100) | - | 178112 (100) | - | 81483 (100) | - |

| Birth                  |           |           |           |           |           |           |           |           |           |           |           |           |           |           |           |
| Vaginal                | 32689 (64.1)| 293 (0.9)| 101897 (57.0)| 818 (0.8)*| 32217 (39.4)| 243 (0.8)*|

* indicates statistically significant differences.
| Cesarean | 18269 (35.9) | 157 (0.9) | 76735 (43.0) | 544 (0.7) | 49450 (60.6) | 213 (0.4) |
|----------|---------------|-----------|--------------|-----------|--------------|-----------|
| 50958 (100) | - | 178632 (100) | - | 81667 (100) | - | |

**Gestational Age**

| < 27 weeks | 213 (0.4) | 119 (55.9)* | 740 (0.4) | 426 (57.6)* | 275 (0.3) | 134 (48.7)* |
| 28 to 31 weeks | 454 (0.9) | 73 (16.1)* | 1446 (0.8) | 186 (12.9)* | 601 (0.7) | 62 (10.3)* |
| 32 to 36 weeks | 4143 (8.1) | 73 (1.8)* | 14400 (8.1) | 189 (1.3)* | 6765 (8.3) | 62 (0.9)* |
| 37 or more | 46036 (90.5) | 178 (0.4) | 161704 (90.7) | 530 (0.3) | 73912 (90.6) | 188 (0.3) |

| Apgar At 5 Minutes | 50846 (100) | - | 178290 (100) | - | 81553 (100) | - |
|< 7 | 608 (1.2) | 112 (18.4)* | 1983 (1.1) | 424 (21.4)* | 606 (0.7) | 124 (20.5)* |
| ≥ 7 | 49896 (98.8) | 311 (0.6) | 175677 (98.9) | 866 (0.5) | 80816 (99.3) | 298 (0.4) |

| MHDIMEDIUM | HIGH | VERY HIGH |
|------------|------|-----------|
| n(%) | n(%) | n(%) |
| TOTAL | DEATH | TOTAL | DEATH | TOTAL | DEATH |

**MHDI**

| Low Weight | 50504 (100) | - | 177660 (100) | - | 81422 (100) | - |
| Low Weight No (≥ 2500 g) | 46473 (91.2) | 180 (0.4) | 163603 (91.6) | 542 (0.3) | 75456 (92.4) | 179 (0.2) |
| Low Weight Yes (< 2500 g) | 4485 (8.8) | 270 (6.0)* | 15031 (8.4) | 820 (5.5)* | 6212 (7.6) | 277 (4.5)* |
In the bivariate analysis, through Poisson’s simple regression, the maternal education equal or superior to 12 years of study was a protective factor for death. In relation to the general MHDI in its three components, the lower its classification, the higher was the risk of child death in the first year of life. Children of mothers residing in the medium MHDI score died 1.58 times more when compared to those of mothers with very high MHDI scores. On the other hand, children of mothers residing in macro-regions with low MHDIE died 1.76 times more often when compared to those of mothers with very high MHDIE (Table 3).

Table 3
Association of the MHDI (and its components) and maternal education on Infant Mortality (unadjusted model) in Porto Alegre in the period 2000 to 2017.
| MHDIL       |       |       |       |       |
|-------------|-------|-------|-------|-------|
| High        | 11246 | 107 (1.0) | 1.32[1.09–1.6] | 0.005 |
| Very high   | 300014 | 2161 (0.7) | 1       |       |

| MHDIE       |       |       |       |       |
|-------------|-------|-------|-------|-------|
| Low         | 58675 | 520 (0.9) | 1.76[1.53–2.03] | < 0.001 |
| Medium      | 133996 | 1067 (0.8) | 1.58[1.39-1.8] | < 0.001 |
| High        | 58978 | 381 (0.6) | 1.284[1.1–1.49] | 0.001 |
| Very high   | 59611 | 300 (0.5) | 1       |       |

| Maternal Education |       |       |       |       |
|--------------------|-------|-------|-------|-------|
| < 8 years          | 90559 | 1074 (1.2) | 3.3[2.91–3.74] | < 0.001 |
| ≥ 8 to 11 years   | 131,638 | 869 (0.7) | 1.84[1.616-2.09] | < 0.001 |
| ≥ 12 years        | 87972 | 316 (0.4) | 1       |       |

Dependent variable: death. RR: relative risk. CI95%: 95% confidence interval. MHDII: Municipal Human Development Index; MHDIII: Income component of the Municipal Human Development Index; MHDIL: Longevity component of the Municipal Human Development Index; MHDIE: Education component of the Municipal Human Development Index. n: number of participants. %: percentage. <: less.

Through Poisson regression adjusted for statistically significant variables in bivariate analysis together with maternal education to assess the influence of the MHDI on infant mortality, no MHDI classification presented association with infant death in the first year of life. The analysis of maternal education showed that a number less than eight years of study maintained association with infant death (p < 0.001) both in the general MHDI and its 3 components, presenting 51 to 54% higher risk for death (Table 4).
Table 4
Association of MHDI and maternal education on Infant Mortality (adjusted model) in Porto Alegre in the period 2000 to 2017.

| MHDI | MHDII | MHDIL | MHDIE |
|------|-------|-------|-------|
| RR[CI95%] | p | RR[CI95%] | p | RR[CI95%] | p | RR[CI95%] | p |
| **MHDII** | | | | | | | |
| Low | - | - | - | - | 1.08 [0.94–1.26] | 0.278 |
| Medium | 1.04 [0.91–1.19] | 0.560 | 1.03 [0.9–1.17] | 0.668 | - | - | 1.05[0.92–1.12] | 0.438 |
| High | 0.98 [0.88–1.09] | 0.680 | 1.01 [0.93–1.1] | 0.769 | 0.96 [0.8–1.16] | 0.677 | 0.95 [0.82–1.11] | 0.541 |
| Very high | 1 | 1 | 1 | 1 | 1 | 1 | |
| **Maternal Education** | | | | | | | |
| < 8 years | 1.53 [1.33–1.77] | < 0.001 | 1.53 [1.32–1.77] | < 0.001 | 1.54 [1.33–1.78] | < 0.001 | 1.51 [1.31–1.75] | < 0.001 |
| ≥ 8 to 11 years | 1.09 [0.95–1.25] | 0.240 | 1.08 [0.94–1.25] | 0.255 | 1.09 [0.95–1.25] | 0.235 | 1.08 [0.94–1.24] | 0.290 |
| ≥ 12 years | 1 | 1 | 1 | 1 | 1 | 1 | |

Dependent variable: death. RR: relative risk. CI95%: 95% confidence interval. MHDI: Municipal Human Development Index; MHDII: Income component of the Municipal Human Development Index; MHDIL: Longevity component of the Municipal Human Development Index; MHDIE: Education component of the Municipal Human Development Index. The model was adjusted for maternal age, parity, number of prenatal care consultations, gestational age, number of dead children, maternal marital status, type of delivery, Apgar, weight (appropriate; low), sex of the infant, type of hospital. n: number of participants. %: percentage. <: less.

4. Discussion

In recent years, different authors have investigated factors related to infant mortality and maternal-infant health conditions. Regarding the influence of socioeconomic factors, the literature has shown that there are differences according to the place studied [17–19]. In the present study, maternal education, individually and jointly analyzed with the MHDI, showed association with the outcome of infant death in the first year of life, particularly for children of mothers with lower maternal education (p < 0.001). In relation to other related factors, maternal age; number of Prenatal Care Consultations; gestational age, weight, gender and Apgar Index (5th minute) of the newborn showed association with IM (p < 0.001) in the municipality of Porto Alegre from 2000 to 2017. These results corroborate previous studies that identified biological and prenatal care factors related to infant death [1, 20–22].

Although most mothers were between 18 and 34 years of age, the highest proportion of child deaths in the first
year of life (1.2%) occurred among the children of those under 18. This age group presents a higher risk for complications, since younger women are still in the phase of physical and psychological development and, part of them, performing their studies in primary, secondary or even higher education [23, 24]. Single, legally separated or widowed women presented a higher risk of death than those married or in a stable union (RR = 1.95; CI95% 1.77–2.15). In literature, other studies have described that the condition of women without a fixed partner negatively affects the health of the mother and child, because it generates some degree of suffering for the woman, who may develop, among other conditions, depression, thus influencing the mother-baby interaction. Moreover, it represented a decrease in emotional and economic support for the family [25–27].

As for the type of birth, most women have had vaginal birth. However, the present study did not evaluate the temporal evolution of this variable, since it is known that this percentage has varied according to the year. Although the evidence does not show an association between cesarean section and a decrease in IM, the number of cesarean sections has been steadily increasing in both developing and developed countries [28, 29]. In 2015, for the first time in Brazil, the number of operative deliveries stabilized [6]. The proportion of cesarean sections was higher in macro-regions with better MHDI scores. This ratio, according to different authors, could be explained by the preference for cesarean sections with higher socioeconomic level, white ethnicity and higher maternal education [30, 31]. Moreover, the most visible discrepancies are observed when comparing cesarean rates in public and private hospitals in several regions of Brazil [31, 32]. These rates in the private sector are significantly higher than in the public health system, exceeding 90% in some hospitals [33, 34].

The MHMI has proven to be an indicator that has a relationship with the variables studied. The lower the classification of the MHDI of the macro-region of maternal residence, the worse were the socioeconomic and demographic conditions. Previous studies that evaluated infant mortality in different regions or ethnic groups found similar results [18, 19]. Cruz and collaborators [17] observed that, in Brazil, women living in more developed regions have lower chances of having an early pregnancy. Approximately, an analysis conducted in Nigeria with population data found that lower maternal age, as well as lower education, especially of mothers who had deceased children showed association with child death [18]. In this context, this same association is found with the worst maternal conditions observed in less developed or developing countries, as well as in regions with lower income and limited access to health services [3, 35].

In the same perspective, although studies show that prenatal care coverage in Brazil has increased by up to 98.7%, the percentage of women with less than 7 prenatal visits is frequent and may vary according to the region analyzed [36, 37]. Data regarding the city in this study showed an improvement of this indicator by 41.71% in the period from 2001 to 2017. However, it is known that this percentage varied according to interurban and health care differences, and there may be regions with adequate Prenatal Care Consultations above 80% and others below 65%[38]. Although the present study did not specifically investigate the annual temporal evolution of prenatal care coverage, these percentages are similar to the results found for this variable.

Research that assessed the influence of the HDI of the maternal home region, when at birth, on health outcomes, showed that this indicator when low is associated with worse outcomes with respect to child neuropsychomotor development [39, 40] and also with higher infant mortality rates [19, 41]. In a study with data from 188 countries, Ruiz and collaborators [41] found that IM was correlated with low HDI and low inequality-adjusted HDI, with the latter being more strongly correlated than the former (Z = 2.524, p = 0.012).

The higher maternal education was not a protective factor for infant death in the first year of life, but, on the contrary, schooling less than eight years of study was a risk factor increasing the chance of death by 51 to 54%, both in the MHDI and its three components. It is assumed that these results are attributed to the worst socioeconomic conditions of that mother and the social and community environment in which she lives with limited access to various resources and health services as well as worse conditions of basic sanitation [22, 42, 43]. Viellas and collaborators [36] found that in Brazil, women with lower education had less prenatal care coverage, fewer prenatal visits and higher utilization of public services. In contrast, they found that those with higher education used more specialized prenatal services, mostly in private services, with monitoring by the same professional throughout pregnancy. In this sense, prenatal care is a process of health education for women and their families, collaborating in the care of pregnancy and children, including, often, the beginning of health care for some individuals, especially adolescents [44].
However, other studies have shown that, in addition to socioeconomic conditions, higher maternal education has improved the child's health conditions and prevented infant mortality. The higher educational level of mothers, together with their better intellectual capacities, help in health choices, increase the understanding and use of information and improve the perception of health problems [45]. They also invest in more health-beneficial behaviors, both at the individual and child levels, showing better adherence to health recommendations in terms of nutrition, exercise and reduction of harmful habits [46–49].

Some particular features of the study are worth highlighting. The study was a pioneer in the country in analyzing the relationship of the MHDI of the different regions of a municipality with infant mortality. It was also unprecedented when comparing the influence of schooling with the MHDI on IM. Furthermore, it used two well consolidated health information systems in the municipality over an extended period of time (2000–2016), which provided a robust database with higher quality in its processing and analysis. On the other hand, it presented some limitations. Among them, the non-use of the race/skin color variable, as it was incomplete in some of the years analyzed, and the use of secondary data with pre-established variables and lack of information on serious diseases and maternal characteristics (income, maternal weight and smoking) and more specific neonatal characteristics (breastfeeding). One hypothesis to explain the difference in the results found with what has already been evidenced in the literature is that just like the HDI, the MHDI when analyzed in macro-regions can hide areas of low development and social vulnerability. This could have influenced the analyses since the MHDI values are distributed to the macro-region, not including in the analytical process the micro-regions classified with low or very low MHDI. Porto Alegre currently has 335 micro-regions [15], of which many have very low MHDI values, especially when analyzing the education component. However, the database used did not have a list with the address codes for each micro-region.

### 5. Conclusions

The maternal conditions presented different characteristics according to the MHDI classification, suggesting that they, as well as the health conditions, present differences according to local development. Future researches that evaluate these differences in more detail may contribute to the development of public policies, considering the peculiarities and disparities among the different regions of a city. Although the HDI is considered a good predictor of infant mortality by some authors, the analyses of the present study did not present an association between the MHDI and death in the first year of life after adjustments for the other variables. Unlike the MHDI, maternal education under eight years of study maintained an association with infant death, proving to be a social determinant with relevant impact on infant mortality. Thus, it is concluded that maternal education, individually, is more important than the region of maternal residence as a predictor of child survival in its first year of life.

### Abbreviations

- IM Infant mortality
- MDG 4 Millennium Development Goal 4
- MDG 3 Millennium Development Goal 3
- HDI Human Development Index
- MHDI Municipal Human Development Index
- MHDII Income Component of the Municipal Human Development Index
- MHDIL Longevity Component of the Municipal Human Development Index
- MHDIE Education Component of the Municipal Human Development Index
Declarations

Ethical Approval

The study was approved by the Research Ethics Committees of Hospital de Clínicas of Porto Alegre and the Research Ethics Committees of Municipal Health Department of Porto Alegre, respectively, under the respective protocol numbers 2,940,235 and 3,153,671.

The Term of Commitment for the Use of Secondary Data was signed for the ethical approval and availability of the two databases (Live Births Information System - SINASC and the Mortality Information System - SIM) by the Non transmissible Vital Events, Diseases and Aggravates Surveillance Team of the General Health Surveillance Coordination of the Porto Alegre Municipal Health Secretariat.

Consent for Publication

Not applicable.

Availability of Data and Materials

The dataset generated by the linkage of the two databases related to the current study are available in the “Anele_CR.sav” repository. For the purpose of maintaining the confidentiality of individuals, the variables number of the Declaration of Live Birth, mother's name and home address number were excluded.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions

Carolina Ribeiro Anele
Preparation of the original project; data collection; data processing and analysis; writing of the preliminary and final version of the manuscript; review and editing.

Vânia Naomi Hirakata
Database organization; data processing and analysis.

Marcelo Zubaran Goldani
Preparation of the original project; writing of the final version of the manuscript.

Clécio Homrich da Silva
Preparation of the original project; data processing and analysis; writing of the final version of the manuscript; project administration.

All authors read and approved the final manuscript.
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Figure 1

Description of the study population: live births and infant deaths in the first year of life in the municipality of Porto Alegre, Brazil (2000-2017).

Source: figure made by the author, 2019.
RS: Rio Grande do Sul.

Source: OBSERVAPOA and PROCEMPA, 2016.

Figure 2
Map of the studied city by districts (Porto Alegre, RS, Brazil).
Figure 3
Map of the studied city by Participatory budgeting Regions - macro-regions (Porto Alegre, RS, Brazil).

**Supplementary Files**

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