Method for estimating infant mortality and low birth weight indicators for Brazilian municipalities, 2012

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Abstract

Objective: to present a method for estimating low birth weight (LBW) prevalence and infant mortality rate (IMR) indicators for Brazilian municipalities, so as to incorporate considerations with regard to sampling fluctuation. **Methods**: binomial and Poisson distributions were used to estimate 95% confidence intervals (95%CI); when the number of infant deaths was zero, the upper limit of the 95%CI was estimated by the cross-multiplication method; indicators were estimated for the year 2012 for demonstration purposes. **Results**: a slight increase in LBW and a decrease in IMR were detected as municipality population size increased; LBW estimates were more accurate than those for IMR; single-year estimates showed large width 95%CI in small municipalities and low reliability. **Conclusion**: an electronic spreadsheet was developed which will allow service managers to estimate the accuracy of these indicators for their municipalities.

Key words: Infant Mortality; Infant, Low Birth Weight; Estimation Techniques; Cities; Epidemiological Surveillance/statistics & numerical data.

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Introduction

Over time, several institutions and national and international entities, some of which participate in public planning and on researches, have developed and improved a range of indicators for analyzing and monitoring the living conditions and health of the population.[1]

In the context of administrative and fiscal decentralization, the demand for social and demographic information on different population levels, including the municipal level, in order to formulate public policies, has been increasing. The knowledge on the limits and potential of social indicators, especially when stratified, is essential for the managers to define more accurately the social priorities and the public resources allocation.[2]

Out of the 5,565 Brazilian municipalities, about 2,100 registered less than 100 live births in 2012, and 1,200, registered between 100 and 200 live births.[3] For the municipalities with a small number of live births, the accuracy in the calculation of infant health indicators – such as low birth weight and infant mortality rate – may be impaired due to annual fluctuation.

The objective of this study was to present a method for estimating low birth weight (LBW) prevalence and infant mortality rate (IMR) indicators for Brazilian municipalities, so as to incorporate considerations with regard to sampling fluctuation. To complement the study, we developed an electronic spreadsheet that will allow managers to estimate the accuracy of future statistics on low birth weight and infant mortality in the municipalities.

Methods

A descriptive ecological study was conducted with data on the total population, the number of live births and the number of infant deaths (infants under one year old) of all the Brazilian municipalities in 2012, in order to demonstrate the proposed method.

The data was taken from the Information System on Live Births (*Sinasc*) and the Mortality Information System (*SIM*), both managed by the Brazilian Ministry of Health. Data on the size of municipalities was obtained from the population census and estimates calculated by the Brazilian Institute of Geography and Statistics (*IBGE*). All the data used was available at the website of the National Health System IT Department (*Datasus*): http://datasus.saude.gov.br.

The infant mortality rate (IMR) was calculated by dividing the number of infants who died in their first year of life by the number of live births in the same municipality and period, and then multiplying by 1,000.

The low birth weight (LBW) prevalence was calculated by dividing the number of low birth weight newborns (lower that 2,500g) by the total number of live births in the same municipality, and then multiplying by 100.

To evaluate the reliability of estimates, the indicators were calculated according to nine municipal population strata: 0-4; 5-9; 10-19; 20-29; 30-49; 50-99; 100-199; 200-499; and 500 thousand inhabitants or more.

> *For the municipalities with a small number of live births, the accuracy in the calculation of infant health indicators may be impaired due to annual fluctuation.*

Two statistical methods were used to estimate the 95% confidence intervals for the LBW and IMR indicators:[4]

a) Binomial distribution – it is recommended for binary variables analysis (e.g.: birth weight, which can be <2,500 grams or ≥2,500 grams) in a finite sample.
b) Poisson distribution – it can be defined as a special case of binomial distribution, when the number of events (e.g.: infant deaths) tends to be much inferior to the denominator (in the case of this study: live births).

With regard to the number of events equal to zero, we proposed an alternative method to estimate the upper limit of the 95% confidence interval (the lower limit, by definition, is equal to zero), taking into account that the null value in the numerator would impair the indicator calculation. This method, known as cross-multiplication method,[5] in the case of infant mortality rate, estimates the upper limit as being equal to three, divided by the number of live births. As in only a few municipalities the number of LBW was zero, the proposed method was used only for IMR.

An Excel spreadsheet was built (Appendix 1, available in Portuguese at the online version) aiming at showing how the service managers should act to estimate the accuracy of the LBW and IMR indicators in their municipalities. Municipal managers can perform their own calculations for these indicators – e.g., for 2013 on – or even aggregate results of 2-3-year periods, because the proposed method enables the acquisition of more stable estimates, with higher numerators and denominators. The spreadsheet allows to type the number of live births, of LBW infants and infant death, and automatically calculates the estimates with 95% confidence intervals. In order to use the aforementioned spreadsheet, it is necessary to install a macro for Excel that can be found in a Microsoft Excel Add-In file (or supplement). To install this file, you have to press the Microsoft Office button in 'Excel options', and then, in Supplements (search the name 'conf int'). When you find the file, click 'yes' to install and follow the instructions. In case you cannot find the file among the available Excel supplements, you have to download the program from the statpages.info, section 'confidence intervals, single-population tests', and install it in the computer following the recommendations of the previous step.

This study used only secondary data, without identifying the individuals. It was conducted in accordance to the ethical principles defined in the National Health Council Resolution (CNS) No. 466, dated 12 December 2012.

Results

Initially, we are presenting the results for the municipalities, and then, the results by municipal population strata.

Results for the Brazilian municipalities

The results obtained in the LBW estimates and infant mortality rates for the 5,565 Brazilian municipalities in 2012 are presented in an Excel spreadsheet (Appendix 2, available online in Portuguese). The spreadsheet includes two pages or tabs: one with simplified results, for service managers; and the other one with detailed comparison between the three methods (binomial, Poisson and cross-multiplication).

Table 1 represents an extract of the Excel spreadsheet of Appendix 2 (tab 'Detailed estimates') and one example of these procedures, with the first 19 of the 5,565 Brazilian municipalities. The first municipality, in alphabetical order, is Abadia de Goiás-GO, where 143 live births were recorded in 2012, counting with 5 low birth weight cases and 1 infant death. The LBW prevalence was 3.5% with 95% confidence intervals (95%CI) from 1.1 to 8.0% (binomial) and from 1.1 to 8.2% (Poisson). For IMR of 7.0 for every 1,000 live births, the 95%CI ranged from 0.2 to 38.3 and 0.2 to 39.0, respectively. The Poisson intervals are slightly wider, although the intervals' overlapping is almost the same, confirming that both methods produced results with similar accuracy. It is important to highlight that the confidence limits were asymmetric in relation to the point estimate, i.e., the upper limit was further from the estimate than the lower limit. The spreadsheet presents the difference between the upper limit and the estimate, which can be interpreted as the margin of error (upper) of the value obtained for the studied year.

Still on Table 1, we can see the example of a municipality with bigger population: Abaetetuba-PA, with 2,532 live births, 214 LBW cases and 44 infant deaths. The LBW prevalence was 8.5%, with binomial distribution and 95%CI ranging from 7.4 to 9.6%, almost the same CI obtained with the Poisson distribution (from 7.4 to 9.7%). The upper limit was only 1.2 p.p. higher than the estimate. The IMR of 17.4 per 1,000 live births presented a binomial 95%CI ranging from 12.7 to 23.3, and the Poisson 95%CI was very close (from 12.6 to 23.3). The margin of error was of 6.0 deaths per one thousand live births.

Out of the 5,565 municipalities analyzed, 1,306 did not report infant death in 2012. This is the case of Abdon Batista-SC that recorded 33 live births, 3 of which presented LBW and zero infant death. Due to the small number of live births, the confidence intervals were wide. In those municipalities that did not present any infant death, the cross-multiplication method was applied: in Abdon Batista-SC, for example, the upper limit of the 95%CI was equal to 90.9 per 1,000 live births, compared to 111.8 according to the Poisson distribution and 105.8, according to binomial distribution.

As the aforementioned spreadsheet is complex, the Excel spreadsheet of the Appendix 2 presents the summarized results, aiming at making the comprehension easier for the service managers: in the 'Summarized Estimates' tab, only the Poisson confidence intervals were presented. This statistical method is more suitable for less frequent events in the population, which is the case of infant deaths. However, the results obtained with the Poisson distribution were very close to those obtained with the binomial distribution in this study.

Figure 1 shows the Excel spreadsheet of the Appendix 1, which will allow the service managers to type the number of live births, of LBW cases and infant deaths

Table 1 – Extract of the Excel spreadsheet for prevalence estimates on low birth weight and infant mortality rate. Brazil, 2012

Municipalities	Code of the municipality	FU[a]	Population	LB[b] (n)	LBW[c] (n)	Low birth weight (%)						Infant deaths (n)	Infant mortality rate (*per* 1000 live births)						
						LBW[c]	Binomial LBW[c] LL[d]	Binomial LBW[c] UL[e]	Poisson LBW[c] LL[d]	Poisson LBW[c] UL[e]	Margino[f] error (p.p)[f]		IMR[g] (/1000)	Binomial IMR[g] LL[a]	Binomial IMR[g] UL[e]	Poisson IMR[g] LL[d]	Poisson IMR[g] UL[e]	UL[e] zero infant death[h]	Margin of error (/1,000)
Abadia de Goiás	5200050	GO	7,164	143	5	3.5	1.1	8.0	1.1	8.2	4.7	1	7.0	0.2	38.3	0.2	39.0		32.0
Abadia dos Dourados	3100104	MG	6,743	68	4	5.9	1.6	14.4	1.6	15.1	9.2	1	14.7	0.4	79.2	0.4	81.9		67.2
Abadiânia	5200100	GO	16,408	205	20	9.8	6.1	14.7	6.0	15.1	5.3	2	9.8	1.2	34.8	1.2	35.2		25.5
Abaeté	3100203	MG	22,740	238	28	11.8	8.0	16.6	7.8	17.0	5.2	5	21.0	6.9	48.3	6.8	49.0		28.0
Abaetetuba	1500107	PA	144,415	2,532	214	8.5	7.4	9.6	7.4	9.7	1.2	44	17.4	12.7	23.3	12.6	23.3		6.0
Abaiara	2300101	CE	10,815	155	15	9.7	5.5	15.5	5.4	16.0	6.3	3	19.4	4.0	55.5	4.0	56.6		37.2
Abaíra	2900108	BA	8,659	53	5	9.4	3.1	20.7	3.1	22.0	12.6	3	56.6	11.8	156.6	11.7	165.4		108.8
Abaré	2900207	BA	17,685	318	24	7.5	4.9	11.0	4.8	11.2	3.7	6	18.9	7.0	40.6	6.9	41.1		22.2
Abatiá	4100103	PR	7,690	97	10	10.3	5.1	18.1	4.9	19.0	8.6	3	30.9	6.4	87.7	6.4	90.4		59.5
Abdon Batista	4200051	SC	2,635	33	3	9.1	1.9	24.3	1.9	26.6	17.5	0	–	–	105.8	–	111.8	90.9	90.9
Abelardo Luz	4200101	SC	17,200	269	18	6.7	4.0	10.4	4.0	10.6	3.9	1	3.7	0.1	20.5	0.1	20.7		17.0
Abel Figueiredo	1500131	PA	6,905	114	7	6.1	2.5	12.2	2.5	12.7	6.5	0	–	–	31.8	–	32.4	26.3	26.3
Abre Campo	1500131	PA	13,306	163	17	10.4	6.2	16.2	6.1	16.7	6.3	1	6.1	0.2	33.7	0.2	34.2		28.0
Abreu e Lima	2600054	PE	95,243	1,394	111	8.0	6.6	9.5	6.6	9.6	1.6	24	17.2	11.1	25.5	11.0	25.6		8.4
Abreulândia	1700251	TO	2,422	27	1	3.7	0.1	19.0	0.1	20.6	16.9	0	–	–	127.7	–	136.6	111.1	111.1
Acaiaca	3100401	MG	3,925	47	5	10.6	3.5	23.1	3.5	24.8	14.2	2	42.6	5.2	145.4	5.2	153.7		111.2
Açailândia	2100055	MA	106,422	1,934	115	5.9	4.9	7.1	4.9	7.1	1.2	19	9.8	5.9	15.3	5.9	15.3		5.5
Acajutiba	2900306	BA	14,730	216	17	7.9	4.7	12.3	4.6	12.6	4.7	5	23.1	7.6	53.2	7.5	54.0		30.9

a) FU: Federation Unit
b) LB: live births
c) LBW: low birth weight
d) LL: lower limit of the 95% confidence interval
e) UL: upper limit of the 95% confidence interval
f) p.p: percentage point
g) IMR: infant mortality rate
h) The cross-multiplication method was used in those municipalities where the number of infant deaths was zero
Note:
The detailed spreadsheet, with all the 5,565 Brazilian municipalities, showing the results according to the binomial, Poisson and cross-multiplication methods is available at the Attachment 2 of the online version of the article, at the tab 'Detailed estimates'.

Calculation of confidence intervals for low birth weight and infant mortality	
Enter the data in the five row below:	
Name of the municipality	Abaeté
Year	2012
Number of live births	238
Number of newborns weighing less than 2,500g	28
Number of infant deaths	5
Results for low birth weight:	
Prevalence of low birth weight	11.8%
Lower limit of the 95% confidence	7.8%
Upper limit of the 95% confidence	17.0%
Results for infant mortality:	
Infant mortality rate per 1,000 live births	21.0
Lower limit of the 95% confidence	6.8
Upper limit of the 95% confidence	49.0

a) The spreadsheet – Excel format – is available at the Appendix 1 of the online version of this article; the confidence intervals was based on the Poisson distribution method.

Figure 1 – Spreadsheet example for calculating the confidence intervals for low birth weight and infant mortality[a]

of their municipalities, and obtain the LBW and IDR estimates with Poisson confidence intervals. In Figure 1, the information related to Abaeté-MG was typed, as an example.

Results for municipal population strata

Table 2 and Figures 2 and 3 present average values of the prevalence estimates for LBW and IDR and their respective Poisson 95%CI, for nine municipal population strata.

Table 2 and Figure 2 show that there was a discrete rise in the prevalence for LBW, as the population size increased. It is possible to notice a large width of the 95%CI in small municipalities. For example, in the group of municipalities with less than 5 thousand inhabitants, the average confidence interval varied from 2.1 to 25.2% for an average prevalence of LBW of 8.1%, and the 95%CI was 2.9 times bigger than the LBW estimate, demonstrating higher inaccuracy in the estimates. The ratio between CI/LBW dropped as the population increased, and this ratio was lower than the unit in the interval from 20,000 to 29,999 inhabitants. In the group of municipalities with 500,000 inhabitants or more, the interval varied from 8.7 to 9.7%, for an average prevalence of LBW of 9.2%, resulting in a ratio between CI/LBW of 0.11.

The variation was even higher for infant mortality (Table 2 and Figure 3), because this is a most rare event and, thus, more difficult to be precisely measured. The ratio between the CI and the IDR was 10.6 in the group with less than 5,000 inhabitants; only in municipalities with 100,000 inhabitants or more, the ratio was lower than the unit. Unlike the low birth weight, the infant mortality presented a slightly reduction trend as the population in the municipalities increased.

Table 3 confirms these observations, showing the difference between the average estimate value and its lower and upper limits of 95%CI for LBW and IDR, according to the population of the municipalities. Once more we can notice that the intervals are unequal, with higher margin of error in the upper intervals.

Discussion

Exploratory analyses were conducted on the reliability of the prevalence indicators for LBW and IDR, according to municipal population strata. It is essential to count

Table 2 – Average values of low birth weight (LBW) prevalence and infant mortality rate (IMR) and the respective 95% confidence intervals of Poisson, according to municipal population strata. Brazil, 2012

Population strata (in million)	Number of municipalities	Total population in each stratum in Brazil	Live births	Newborns with LBW	Average values						
					LBW[a] prevalence (%)	Lower limit (%)	Upper limit (%)	Infant deaths	IMR[b]	Lower limit	Upper limit
0-4	1,298	3,368	40	3	8.1	2.1	25.2	0.5	13.2	1.1	141.5
5-9	1,209	7,079	92	7	7.8	3.2	16.4	1.4	14.5	2.3	70.7
10-19	1,389	14,157	197	15	7.6	4.2	12.8	2.9	14.4	3.5	45.0
20-29	590	24,271	357	27	7.8	5.1	11.4	5.4	14.9	5.5	34.4
30-49	465	37,900	576	44	7.7	5.6	10.4	8.5	14.7	6.6	28.7
50-99	326	69,152	1,060	84	8.0	6.3	9.9	14.9	13.8	7.7	23.1
100-199	152	134,523	2,090	181	8.7	7.4	10.1	27.0	12.7	8.4	18.7
200-499	98	302,987	4,772	424	8.9	8.1	9.8	61.1	12.6	9.6	16.4
≥500	38	1,493,543	22,512	2091	9.2	8.7	9.7	280.2	12.5	10.7	14.4

a) LBW: low birth weight
b) IMR: infant mortality rate

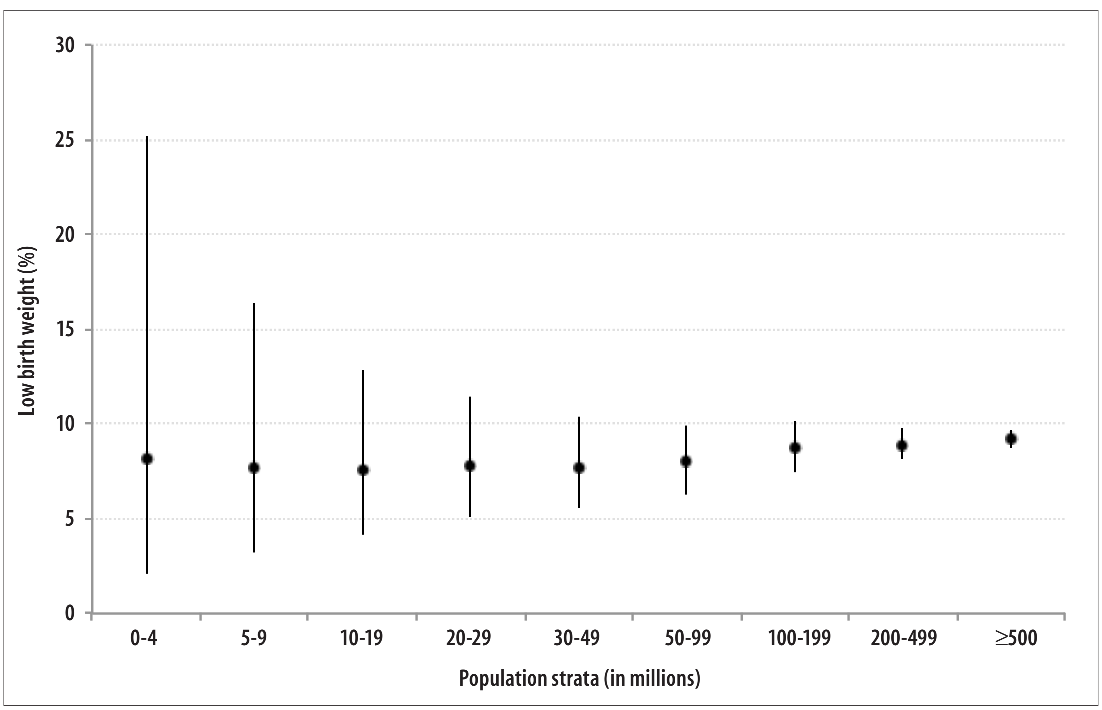

Figure 2 – Average values of low birth weight (LBW) prevalence and 95% confidence intervals of Poisson, according to municipal population strata. Brazil, 2012

with good quality disaggregated data on a municipal level for a suitable health management. The processes of planning and management in the municipalities demand a global and continuous diagnosis on local reality. The decentralized information on municipal level provide essential data for planning, diagnosing and monitoring the local conditions, allowing the service managers to conduct a decentralized management.[6] However, the low human resources qualification and the little knowledge on the information systems, among other problems, may bind the bolstering and reliability of the information presented in national databases and impair the evaluation of the population health situation.[7,8]

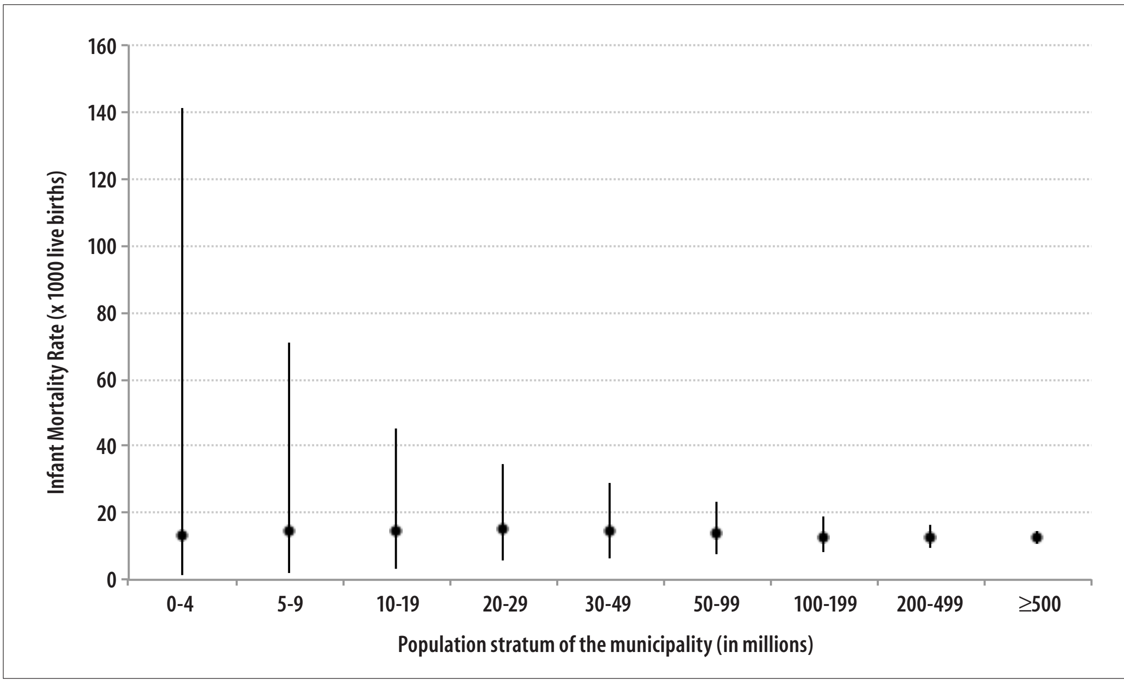

Figure 3 – Average values of infant mortality rate and 95% confidence intervals of Poisson, according to municipal population strata. Brazil, 2012

Table 3 – Differences between the estimate average value and the lower and upper limits of 95% confidence for the prevalence of low birth weight (LBW) and the infant mortality rate (IMR), according to municipal population strata. Brazil, 2012

Population strata (in million)	LBW[a] (%)		IMR[b] (*per* 1000 live births)		Number of municipalities
	Lower limit	Upper limit	Lower limit	Upper limit	
0-4	-6.0	17.1	-12.2	113.2	1,298
5-9	-4.6	8.6	-12.2	53.1	1,209
10-19	-3.4	5.2	-10.8	30.2	1,389
20-29	-2.7	3.6	-9.5	19.4	590
30-49	-2.1	2.7	-8.0	14.1	465
50-99	-1.6	1.9	-6.1	9.3	326
100-199	-1.2	1.4	-4.4	6.0	152
200-499	-0.9	0.9	-3.0	3.7	98
≥500	-0.5	0.5	-1.7	2.0	38
Total	-3.9	7.9	-10.4	49.5	5,565

a) LBW: low birth weight
b) IMR: infant mortality rate

Although the number of LBW live births and infant deaths include all the events recorded on the national systems (*Sinasc* and *SIM*, respectively) and not a sample of these events, in statistical analyses it is important to suppose the existence of information loss and apply techniques that allow the accurate calculation (confidence interval) of the estimates.[9]

The main findings of these analyses were already expected, because the dependency on accuracy of the estimates related to the studied group is well known[10] – in this case, the annual number of live births. The bigger the sample size is, the more accurate the calculated estimates will be. This accuracy also depends on the frequency of the outcome studied. In the present analyses, for each population group considered, confidence intervals of the LBW estimates were always smaller (showing higher estimate accuracy) than the confidence intervals for IDR. This may happen because the LBW is a more frequent event than the infant death, and, for the sample size, the accuracy of the estimates will be higher if the studied event is more frequent. When the number of infant deaths and the number of live births were zero, the three analyzed methods presented varied results, although all of them were close to 100 per 1,000 live births.

The decision on what would represent an acceptable accuracy level is, in great part, arbitrary. With regard to LBW, the municipalities with more than 20,000 inhabitants presented more accurate estimates, with CI lower than the average value of the prevalence; still, the average 95%CI varied from 5.1 to 11.4%. Concerning the IDR, the 95%CI was inferior to the average value only in municipalities with more than 100,000 inhabitants, where it varied from 8.4 to 18.7 per 1,000. Nevertheless, for both indicators the upper limit was more than double of the lower limit, showing important inaccuracy.

In the past decades, the Ministry of Health has developed several programs that focus on reducing infant mortality.[11] The monitoring of infant mortality trends from vital information of the Ministry of Health, with the direct calculation of the indicator using information from *SIM* and *Sinasc*, is accepted in those Brazilian states with information on live births and deaths that are considered suitable.[12] The quality on the information systems has been improving as a whole.[13-15] In a cohort study conducted in Pelotas-RS, with live births in 1982, 1993 and 2004, the researchers observed an improvement in the registration of deaths coverage along the studied period and zero infant deaths in that municipality in 2004.[16]

Several strategies have been proposed for estimating infant mortality in smaller municipalities using the information systems of the Ministry of Health, or where there is incomplete or irregular coverage of the vital records.[17] Recently, some strategies, such as estimating correction factors for vital information and infant mortality per municipality[18] and the use of spacial analyses methods[19] have contributed to overcome the instability of LBW estimates in areas with small population.

It is important to highlight that the present analyses are restricted to statistical and sample fluctuations and, therefore, do not take into consideration systematic errors – case of the underreporting of events that can impact the municipal level estimates.

In future analyses, the accuracy of the estimates presented in the present study can be enhanced. For instance, it is possible to aggregate events (live births and deaths) occurred in two, three or more years, reducing the margin of error, but impairing the updating of estimates. If the long-term behavior presents pre-defined patterns (such as progressive reduction or raise), regression techniques can be used to improve the accuracy of certain estimates. Analysis strategies that include risk factors for mortality – e.g., socio-economical, environment, and assistance data –, although they are important, they depend greatly on correctly specifying the analysis model to be used and the accurate measure of the explanatory variables.[20,21]

It is necessary to motivate the municipal managers for using mortality and live births data for building health indicators and assisting the correct interpretation of these indicators, which will lead to an adequate analysis of the health situation on a local level.

The main contribution of this article is to demonstrate that the municipal estimates, for the most part, of the Brazilian municipalities present low reliability if analyzed only in a specific year. The offer of a simple tool to estimate confidence intervals may contribute to the adequate interpretation of statistical reliability for low birth weight and infant mortality. The proposed tool can be useful for detecting priority municipalities, implementing actions for improving vital information and organizing the health care network on mother-children health.

Authors' contributions

Victora CG and Matijasevich A contributed to the formulation of the research question and of the study design, participated in the analysis and interpretation of results and manuscript drafting. Cortez-Escalante JJ, Rabello Neto D and Fernandes RM contributed to the interpretation of findings and final drafting of the manuscript.

All the authors have approved the final version of the manuscript and are responsible for all the work aspects, ensuring its accuracy and integrity.

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