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The epidemiologic paradox of low birth weight in Brazil

O paradoxo epidemiológico do baixo peso ao nascer no Brasil

ABSTRACT

OBJECTIVE: To examine whether the low birth weight (LBW) paradox exists in Brazil.

METHODS: LBW and cesarean section rates between 1995 and 2007 were estimated based on data from SINASC (Brazilian Live Births Database). Infant mortality rates (IMRs) were obtained using an indirect method that correct for underreporting. Schooling information was obtained from census data. Trends in LBW rate were assessed using joinpoint regression models. The correlations between LBW rate and other indicators were graphically assessed by lowess regression and tested using Spearman's rank correlation.

RESULTS: In Brazil, LBW rate trends were non-linear and non-significant: the rate dropped from 7.9% in 1995 to 7.7% in 2000, then increased to 8.2% in 2003 and remained nearly steady thereafter at 8.2% in 2007. However, trends varied among Brazilian regions: there were significant increases in the North from 1999 to 2003 (2.7% per year), and in the South (1.0% per year) and Central-West regions (0.6% per year) from 1995 to 2007. For the entire period studied, higher LBW and lower IMRs were seen in more developed compared to less developed regions. In Brazilian States, in 2005, the higher the IMR rate, the lower the LBW rate ($p=0.009$); the lower the low schooling rate, the lower the LBW rate ($p=0.007$); the higher the number of neonatal intensive care beds per 1,000 live births, the higher the LBW rate ($p=0.036$).

CONCLUSIONS: The low birth weight paradox was seen in Brazil. LBW rate is increasing in some Brazilian regions. Regional differences in LBW rate seem to be more associated to availability of perinatal care services than underlying social conditions.

DESCRIPTORS: Infant, Low Birth Weight. Infant Mortality. Cesarean Section. Perinatal Care. Brazil.

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RESUMO

OBJETIVO: Identificar a presença do paradoxo do baixo peso ao nascer (BPN) no Brasil.

MÉTODOS: As taxas de BPN e de cesárea, de 1995 a 2007, foram estimadas a partir do Sistema de Informações sobre Nascidos Vivos. As taxas de mortalidade infantil, foram calculadas por métodos indiretos, com correção para sub-registro. A taxa de escolaridade foi obtida de dados censitários. As tendências da taxa de BPN foram avaliadas utilizando-se modelos de regressão *joinpoint*. As associações entre a taxa de BPN com outros indicadores foram avaliadas por regressão *lowess* e correlação de Spearman.

RESULTADOS: No Brasil, as tendências da taxa de BPN foram não lineares e não significantes: a taxa caiu de 7,9% em 1995 para 7,7% em 2000, aumentando para 8,2% em 2003 e permanecendo estável em 8,2% em 2007. Entretanto, as tendências variaram nas regiões brasileiras: houve aumentos significantes no Norte (2,7% por ano), de 1999 a 2003, e no Sul (1,0% por ano) e Centro-Oeste (0,6% por ano), de 1995 a 2007. As taxas de BPN foram mais altas e as taxas de mortalidade infantil mais baixas nas regiões mais desenvolvidas do que nas menos desenvolvidas. Em 2005, quanto mais elevada a taxa de mortalidade infantil, menor foi a taxa de BPN ($p = 0,009$); quanto mais alta a taxa de baixa escolaridade, menor foi a taxa de BPN ($p = 0,007$); quanto maior o número de leitos de terapia intensiva neonatal por 1.000 nascidos vivos, mais elevada foi a taxa de BPN ($p = 0,036$).

CONCLUSÕES: O paradoxo do BPN foi detectado no Brasil. A taxa de BPN está aumentando em algumas regiões brasileiras. Diferenças regionais na taxa de BPN parecem estar mais relacionadas à disponibilidade de assistência perinatal do que às condições sociais.

DESCRIPTORIOS: Recém-Nascido de Baixo Peso. Mortalidade Infantil. Cesárea. Assistência Perinatal. Brasil.

INTRODUCTION

Low birth weight (LBW) rate is defined as the proportion of live births < 2,500 grams and it has been classically considered a marker of social development. LBW rates are expected to be lower in more developed settings¹⁶ and the lower the LBW rates the lower the infant mortality rates (IMR). In Brazil, in the 1960s and 1970s, LBW rate ($\leq 2,500$ g) was lower in Ribeirão Preto (8.7% in 1968–1970), a more developed city in Southeast Brazil,¹⁶ than in three maternity hospitals in Recife (14.6% in 1974), a less developed city in Northeast Brazil,^{14,16} whereas IMR was higher in Recife (91.2 per thousand in 1969) than in Ribeirão Preto (52.5 per thousand in 1968–1970).^{12,15} In addition, LBW rate tended to decrease as economic development and life conditions improved, as seen in Recife, where it dropped from 14.6% in 1974¹⁴ to 9.1% in 2005.^a

However, LBW rates have been recently found to be higher in more developed (South and Southeast) than

in less developed regions (North and Northeast) in Brazil. LBW rate is higher in regions where IMR is lower.¹³ In some Brazilian cities with improving life conditions, LBW rate is increasing, e.g., it increased in Ribeirão Preto from 7.6% in 1978–1979 to 10.6% in 1994.¹⁷ In the Southern city of Pelotas, LBW rate also increased from 9.0% in 1982 to 10.4% in 2004.³ Increasing LBW rates have also been reported in other countries such as the USA where it rose from 6.8% in 1980 to 7.6% in 2000.⁴

The so-called epidemiologic paradox of low birth weight seems to exist in Brazil where higher LBW rates are seen in more developed regions and lower rates in less developed ones. This paradox has also been described in the USA where Hispanic women of lower socioeconomic status have lower LBW rates compared to better-off white women.⁶ The most accepted explanation for this paradox in Brazil is that it reflects poor

^a Ministério da Saúde. Nascidos vivos - Pernambuco. Nascimentos por residência da mãe segundo peso ao nascer. Município: Recife. Período: 2005. Brasília; 2005 [cited 2007 Dec 08]. Available from: <http://tabnet.datasus.gov.br/cgi/tabcgi.exe?sinasc/cnv/nvpe.def>

data quality due to underreporting of live births in less developed regions.¹³

However, not only higher LBW rates are seen in more developed regions but also IMR is decreasing in all Brazilian regions with improved health care. The explanation that LBW paradox is due to underreporting of live births in less developed regions has been challenged. Data from population studies which are less prone to underreport live births have consistently shown higher LBW rate in the more developed city of Ribeirão Preto than in the less developed city of São Luís.^{20,21} It is not clear whether this paradox is a true epidemiologic phenomenon similar to that described in developed countries where increasing LBW rates have been associated with increasing medical interventions.⁹

The objective of the present study was to examine whether the so-called low birth weight paradox exists in Brazil.

METHODS

Brazil is divided into five geographical regions and 27 states. The South and Southeast regions are the most developed and the North and Northeast are the least developed, while the Central-West region lies somewhere in the middle.

LBW rate was calculated based on data from the Brazilian Live Births Database (SINASC). For comparison purposes, newborns weighing <500 g and those with missing birth weight information were excluded from the analyses. LBW rate trends in the five Brazilian regions were assessed from 1995 to 2007.

The IMR from 2005 was obtained from the most recent information available in the 2007 Brazilian Basic Data and Indicators (IDB-2007).^b It was calculated directly from the Brazilian Mortality Database (SIM) and SINASC for Brazilian states where SIM coverage and regular data flow was 80% or higher and SINASC coverage was 90% or higher. Since underreporting of live births prevents direct calculations of IMR in the least developed Brazilian regions, for all other states the IMR was obtained by indirect methods.^b A variant of the Brass demographic technique proposed by

Trussel and Coale-Trussel was used. Based on census and the Brazilian National Household Study (PNAD) data on live births and living children at the time of interview, death proportions according to maternal age were used to estimate the probability of child death at each age. Fecundity rates were obtained using the questions on total number of live-born children who were born in the last 12 months and then used to estimate the number of live births.^c

SINASC coverage was calculated by dividing the actual number of live births by the estimated number of live births.^d The estimated number of live births was obtained from the Brazilian Institute of Geography and Statistics (IBGE) demographic estimates based on mortality, fecundity and migration projections using the method of components.^e

Less than one year of schooling information among those aged 15 years or more was obtained from IBGE database for socioeconomic indicators.^f Cesarean section rates were obtained from SINASC. The number of neonatal intensive care beds available in each state was obtained from the Brazilian National Registry of Health Services (CNES),^g which was then divided by 1,000 live births to control for population size. Cesarean section rates and number of neonatal intensive care beds per 1,000 live births were taken as proxies of medical intervention.

All data were summarized from the last year with complete information on all variables.

To identify significant trend changes, we carried out a joinpoint regression analysis using the US National Cancer Institute Surveillance Research Program software.^h The Joinpoint Regression Program was used to find the best-fit line through several years of data by using an algorithm that tests whether a multi-segmented line is a significantly better fit than a straight or less-segmented line. Trends of low birth weight data were described through joinpoint regression analysis, which involves fitting a series of joined straight lines on a log scale to the trends in the annual rates. Line segments were joined at points called joinpoints. Each joinpoint denotes a statistically significant ($p < 0.05$) change in trend. The significance tests use a Monte

^b Ministério da Saúde. Taxa de mortalidade infantil. Número de óbitos infantis (menores de 1 ano) por 1.000 nascidos vivos. Brasil, 1997-2005. Brasília; 2005[cited 2009 May 06]. Available from: <http://tabnet.datasus.gov.br/cgi/idb2007/c01.htm>

^c Simões CC. Brasil. Estimativas da mortalidade infantil por microrregiões e municípios. Brasília: Ministério da Saúde; 1999.

^d Ministério da Saúde. F.10 Razão entre nascidos vivos informados e estimados. Razão por ano, segundo Região e UF, Brasil, 1994 a 2005. Brasília; 2005[cited 2009 May 06]. Available from: <http://tabnet.datasus.gov.br/cgi/idb2007/f10.htm>

^e Instituto Brasileiro de Geografia e Estatística. Projeções de população do Brasil, grandes regiões e unidades de federação, por sexo e idade, para o período 1991-2030. Rio de Janeiro; 2004.

^f Ministério da Saúde. Níveis de escolaridade da população de 15 anos e mais. Taxa de escolaridade (%) segundo Região, 2005. Brasília; 2005[cited 2009 May 06]. Available from: <http://tabnet.datasus.gov.br/cgi/tabcgi.exe?idb2007/b02.def>

^g Ministério da Saúde. Cadastro Nacional de Estabelecimentos de Saúde. Brasília; 2000[cited 2007 Dec 08]. Available from: http://cnes.datasus.gov.br/Mod_Ind_Tipo_Leito.asp?VEstado=http://cnes.datasus.gov.br/Mod_Ind_Leitos_Listar.asp?VCod_Leito=63&VTipo_Leito=3&VListar=1&VEstado=&VMun=

^h National Cancer Institute. Joinpoint Regression Program, Version 3.3. Rockfield; 2009[cited 2009 May 06]. Available from: <http://srab.cancer.gov/joinpoint/>

Carlo Permutation method (i.e. it finds “the best fit” line for each segment).¹⁰ In our analysis, a maximum of three joinpoints (four line segments) was allowed for each model. Once line segments were established, the estimated annual percent change was used to describe and test the statistical significance of trends. Testing the hypothesis (two-sided p -value = 0.05) that the annual percent change is equal to zero is equivalent to testing the hypothesis that LBW trend is neither increasing nor decreasing.

For 2005, correlations between LBW and IMR, cesarean section rates, proportion of individuals aged 15 years or more with less than one year of schooling, and number of neonatal intensive care beds per 1,000 live births were graphically assessed by lowess regression and tested using Spearman’s rank correlation because of non-linearity. The level of significance was set at 0.05. Lowess regression is a locally weighted linear regression to smooth data, it makes no assumptions on the nature of relationship and allows to assess it using the data itself.⁵

The Wilcoxon-Russell method was used for an indirect estimate of small preterm birth rate using information on birth weight distribution.²⁴ The frequency distribution of birth weight is approximately normal with an extended lower tail. The normal component of birth weight distribution is called predominant distribution and closely corresponds to the birth weight distribution of term births. The tail is called residual distribution and comprises small preterm babies. The cut-off point between predominant and residual distributions was based on serial and decreasing points immediately below the population’s mean weight estimated using an online software.²⁴ An indirect method to estimate small preterm birth rate was chosen because it is not clear whether SINASC data is valid for the estimation of preterm birth rate. Although a study concluded that there was good agreement on gestational age between SINASC and data from a population-based study,²³ another study found poor agreement between SINASC and cohort data.¹⁸

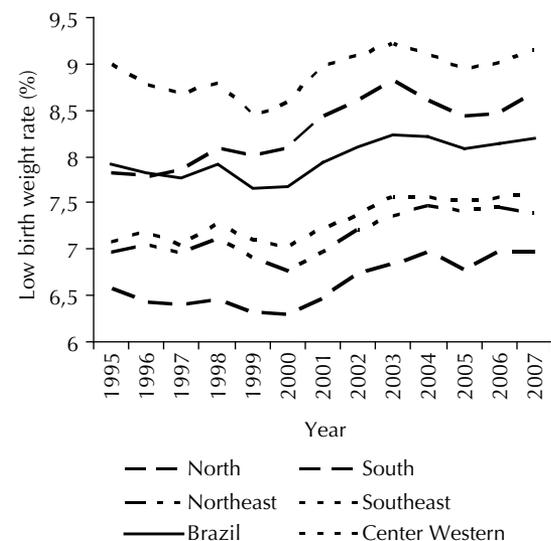
RESULTS

In Brazil, LBW rate trends were non-linear and non-significant: the rate dropped from 7.9% in 1995 to 7.7% in 2000, then increased to 8.2% in 2003 and remained nearly steady thereafter at 8.2% in 2007. For the entire period studied, LBW rates varied in different regions: lower rates were found in less developed regions (North, Northeast and Central-West) and higher rates in more developed ones (Southeast and South), sharply contrasting to what was expected. In 2007, the highest LBW rate was seen in the Southeast (9.1%) and the lowest in the North (7.0%) (Figure 1).

The joinpoint analysis showed that trends varied among Brazilian regions. In the Northeast and Southeast, LBW rate dropped from 1995 to 1999–2000, then increased until 2002–2004 and leveled off. Trends in Brazil, in the Southeast and Northeast regions were non-linear and non-significant. In the Southeast, LBW rate in 2007 was practically the same as that seen in 1995. However, there were significant increases in the North from 1999 to 2003 (2.7% per year), in the South from 1995 to 2007 (1.0% per year) and in the Central-West (0.6% per year) (Table 1).

In 2005, LBW rates were higher in more developed regions (South and Southeast) with higher small preterm birth rates. Small preterm birth rate estimated by the percentage of birth weights in the residual distribution using the Wilcoxon-Russell method was higher in more developed (3.2% and 3.1% in the Southeast and South, respectively) than in less developed regions (2.2%, 2.6% and 2.7% in the North, Northeast and Central-West, respectively). Conversely, mean birth weights were higher in less developed (3,287 g in the Northeast) than in more developed regions (3,210 g in the Southeast), a difference of 77 g (Table 2).

In 2005, SINASC coverage was higher than 85% in all regions. IMRs were lower in more developed (14.2 per 1,000 in the Southeast) than in less developed regions (31.6 per 1,000 in the Northeast). IMRs were higher where the proportion of individuals aged 15 year or more with less than one year of schooling were also higher (Table 2).



^a Low birth weight rate was derived from SINASC ((Brazilian Live Births Database). Newborns weighing < 500g were excluded from calculations.

Figure 1. Low birth weight rates^a in Brazil nationwide and five regions. Brazil, 1995–2007.

Table 1. Joinpoint regression analysis of LBW rate trends in Brazil nationwide and five regions. Brazil, 1995-2007.

Region	Trend 1		Trend 2		Trend 3	
	Years	APC	Years	APC	Years	APC
Brazil	1995-2000	-0.47	2000-2003	2.23	2003-2007	-0.28
North	1995-1999	-1.68 ^a	1999-2003	2.70 ^a	2003-2007	0.34
Northeast	1995-2000	-0.63	2000-2004	2.30	2004-2007	-0.40
Southeast	1995-1999	-1.21	1999-2002	2.26	2002-2007	-0.15
South	1995-2007	1.02 ^a				
Central-West	1995-2007	0.63 ^a				

Note: APC, estimated annual percent of change. The joinpoint analysis allowed for up to three joinpoints and is based on LBW rates obtained from the Brazilian Live Births Database (SINASC). Newborns weighing <500 g were excluded from the analyses.

^a Significantly different from 0 ($p < 0.05$).

Table 2. Low birth weight rate, percent residual distribution, and mean and standard deviation of the main distribution, live births reporting coverage, infant mortality and proportion of individuals with less than one year of schooling in five Brazilian regions. Brazil, 2005.

Region	Low birth weight rate (%) ^a	Residual distribution (%) ^b	Main distribution Mean birth weight (standard deviation) (g) ^b	Live births coverage (%) ^c	Infant mortality rate (per thousand) ^d	Proportion of individuals aged 15 or more with less than one year of schooling (%) ^e
North	6.79	2.2	3278 (467)	95.12	23.35	13.37
Northeast	7.41	2.6	3287 (477)	85.22	31.61	21.21
Southeast	8.95	3.2	3210 (457)	94.13	14.20	7.90
South	8.44	3.1	3242 (464)	99.31	13.80	7.19
Central-West	7.51	2.7	3257 (457)	96.09	17.83	10.54
Brazil	8.09	2.8	3248 (467)	92.06	21.17	11.91

^a LBW rate was obtained from the Brazilian Live Births Database (SINASC). Infants weighing <500 g were excluded from the analyses.

^b Percent residual distribution, mean and standard deviation of the main distribution were estimated using the Wilcoxon & Russell method.²⁴

^c Ratio between the number of actual and estimated live births. Source: Rede Interagencial de Informações para Saúde. Indicadores de cobertura. [cited 2010 Jul 15] Available from: <http://tabnet.datasus.gov.br/cgi/ibd2007/f10.htm>

^d Source: Rede Interagencial de Informações para Saúde. Indicadores de mortalidade. [cited 2010 Jul 15] Available from: <http://tabnet.datasus.gov.br/cgi/ibd2007/c01.htm>

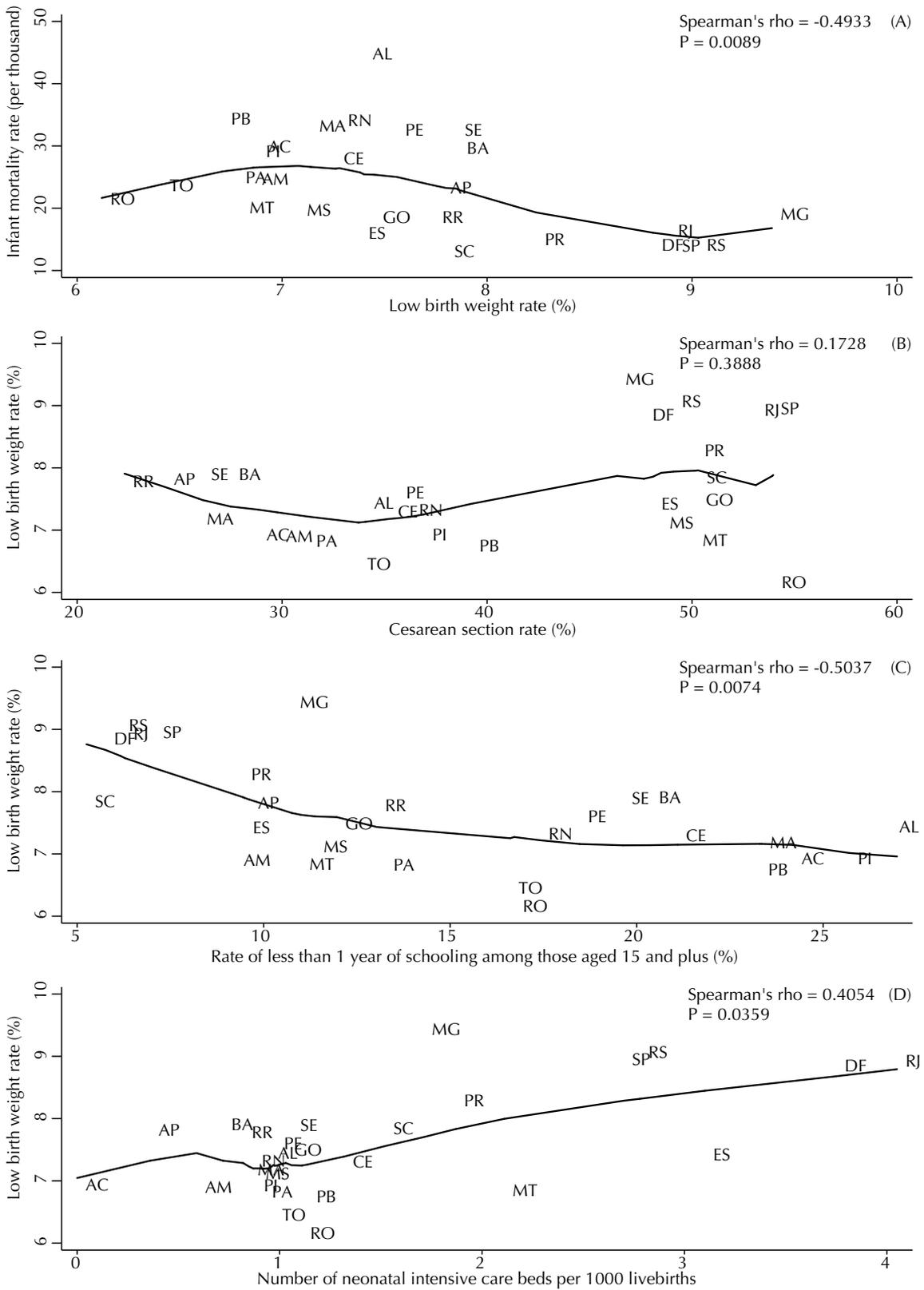
^e Source: Rede Interagencial de Informações para Saúde. Indicadores socioeconômicos. [cited 2010 Jul 15] Available from: <http://tabnet.datasus.gov.br/cgi/tabcgi.exe?ibd2007/b02.def>

In 2005, IMRs and LBW rates were negatively correlated ($p=0.009$). More developed states had higher LBW rates and lower IMRs (Figure 2A). LBW rate was not correlated with cesarean section rate ($p=0.389$) (Figure 2B). However, data suggest a non-linear trend: when cesarean section rates were around 30% LBW rates tended to decline as cesarean section increased. But when the rates were higher than 30% LBW rates tended to increase with cesarean sections. The higher the proportion of individuals with low schooling in a state, the lower the LBW rate ($p=0.007$) (Figure 2C). The higher the number of neonatal intensive care beds per 1,000 live births the higher the LBW rate ($p=0.036$) (Figure 2D).

DISCUSSION

From 1995 to 2007, no significant LBW rate trend was evident in Brazil nationwide: it decreased from 1995 to 2000, then increased until 2003 and remained practically steady thereafter. However, trends varied among Brazilian regions. There were significant increases in the North from 1999 to 2006, and in the South and Central-West from 1995 to 2007. Brazilian regions seem to be at different stages of epidemiological perinatal transition. LBW rates are still increasing in some regions whereas they have leveled off in others. An increase in LBW rate has also been described in developed countries such as the US⁴ and Canada.¹ Brazilian

¹ Ohlsson A, Shah P. Determinants and Prevention of Low Birth Weight: A Synopsis of the Evidence. [cited 2010 Jul 26]. Available from: www.ihe.ca/documents/IHE_Report_LowBirthWeight_final.pdf



^a Letters represent Brazilian states.

Figure 2. Correlations between low birth weight rate and infant mortality rate (A), cesarean section rate (B), rate of less than one year of schooling among those aged 15 or more (C), and number of neonatal intensive care beds per 1,000 livebirths (D) in Brazilian states.^a Brazil, 2005.

birth cohort studies from Ribeirão Preto¹¹ and Pelotas³ have also reported increasing LBW rates.

For the entire period studied, LBW rates varied among regions and were lower in less developed (North, Northeast and Central-West) and higher in more developed regions (Southeast and South), sharply contrasting to what was expected. A low LBW rate among less privileged women has also been reported in women of Mexican origin in the US, a phenomenon that cannot be explained by underreporting of live births among these women or their lower preterm birth rate.⁶ In Portugal, mean birth weight of white babies was lower than that of term babies of foreign-born African mothers. These differences were attributable to a combination of biologic factors and smoking.⁸ The paradox of higher LBW rates in more developed cities has also been previously described in Brazil. LBW rate was higher in Ribeirão Preto than in the less developed city of São Luís in the 1990s.^{20,21}

The explanation for the LBW paradox in Brazil is that low SINASC coverage has been associated with higher underreporting of live births < 1000 g at the limit of viability in less developed regions.¹³ However, huge differences in LBW rate between regions showing SINASC coverage rates higher than 90% persist despite increasing reporting over time as shown here. It suggests that underreporting of live births is not the single explanation for the epidemiologic paradox of LBW but other factors may be also involved. High maternal smoking rates, multiple birth rates and high use of assisted reproduction techniques in more developed regions have also been linked to this paradox.^{20,21} A study conducted in a developed Brazilian region has reported that increased multiple birth rate have contributed to the rise in overall LBW rate.²²

The increasing use of medical interventions in more developed settings has also been closely related to increasing LBW rates in Brazil^{3,17} and elsewhere.⁹ Possibly high rates of LBW seen in more developed regions not only reflect high data reliability but also high quality of perinatal care. Improved medical care provided during pregnancy may be allowing the detection of some conditions such as intrauterine growth restriction and early medical interventions may then take place, rescuing fetuses that otherwise would be born dead but at the same time increasing LBW rate.^{2,9,19} This finding is consistent with that found in our study: a high correlation between the number of neonatal intensive care beds available per 1,000 live births and LBW rate seen in Brazilian states. This phenomenon of decreasing IMRs and increasing LBW and preterm birth rates associated with medical interventions has also been reported in developed countries such as the US and Canada.^{4,9}

Another factor that may explain high LBW rates in more developed Brazilian regions (South and Southeast) is high cesarean section rates. However, in the present study, no linear correlation was found between cesarean section and LBW rate. However, our data suggest that, when cesarean section rates were up to 30%, the higher the cesarean section rate the lower the LBW rate; but, when cesarean section rates were higher, LBW rate tended to increase with increasing cesarean section rates. More developed regions (South and Southeast) showed the highest rates of small preterm babies, estimated by the Wilcoxon-Russell method, the lowest mean birth weights and the lowest proportions of individuals aged 15 and plus with very low schooling. These regions also had the highest SINASC coverage rates. Moreover, states in these regions had the highest LBW rates and lowest IMRs. The correlation between LBW rate and IMR was negative, which is in contrast to what was expected. This ecologic dissociation between LBW rate and IMR may be reflecting improved medical interventions in more developed states. These interventions are associated with increased LBW rate and decreased IMR. Decreasing IMR in Brazil has been reported to be more related to a reduction in birth weight-specific mortality rates than to a decrease in LBW rate.^{3,7}

The epidemiologic paradox of LBW being higher in more developed regions does not seem to reflect an unfavorable health situation and to be related only to reporting or data collection artifacts associated with low SINASC coverage in less developed regions. Despite the socioeconomic growth seen in Brazil in the last two decades, LBW rate is increasing in some regions whereas IMR continues to decline. This ecological dissociation between LBW rate and IMR suggests that LBW rate can no longer be systematically considered an indicator of socioeconomic well-being. It seems that LBW rate is nowadays more associated with access to and availability of perinatal technologies than with underlying socioeconomic conditions. If this is the case, the high LBW rates seen in more developed regions do not constitute a paradox but do reflect improved medical care as measured by decreasing IMRs.

The present study has some limitations. Since underreporting of stillbirths is estimated to be as high as 20% in less developed Brazilian regions, data on stillbirths were not presented. The use of indirect methods to estimate IMR is another limitation. They are useful approaches but rely on assumptions that may not be always true.¹ Moreover, ecologic analysis is subject to ecologic fallacy. Higher availability of neonatal intensive care beds per 1,000 live births was assumed to result in high LBW rates but the possibility of reverse causality – high LBW rates demanding higher availability of neonatal intensive care units – cannot be

¹ Simões CC. Brasil. Estimativas da mortalidade infantil por microrregiões e municípios. Brasília: Ministério da Saúde; 1999.

completely ruled out. SINASC coverage in the North and Northeast reached 80% only from 2001 onwards thus trend analysis for these two regions are subject to bias. It is possible that before when SINASC coverage was lower than 80%, underreporting of live births was higher than in recent years.^{1,13}

The joinpoint analysis of LBW rate trends allows the user to “systematically” interpret changes over time and, more importantly, to determine whether these changes are statistically significant. Joinpoint analysis allowed statistical testing of the direction and magnitude of LBW trends in Brazilian regions with the detection of some significant changes. It can provide a much clear

picture of what is happening during a certain period of time in specific terms (by identifying the years when there were significant changes in trends) than a single summary trend statistical analysis.

In conclusion, LBW rate is increasing in some Brazilian regions whereas it has leveled off in others. LBW rate showed a positive correlation with proxy indicators of neonatal care and a negative correlation with socioeconomic factors and IMR. It suggests that the regional differences seen in LBW rate in Brazil seem to be more related to the availability of perinatal health services and medical interventions than to underlying social conditions.

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