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Early Infant Morbidity in the City of São Paulo, Brazil

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Abstract

Background: Early infant morbidities may produce adverse outcomes in subsequent life. A low Apgar score is a convenient measure of early infant morbidity. We study determinants of early infant morbidity (sex, plurality, mode of delivery, prior losses, gestational age, prenatal care and birth weight, parity and maternal age, race, maternal education and community development) for the 1998-birth cohort, City of São Paulo, Brazil.

Methods: This study identified all deliveries that took place in the City of São Paulo during 1998. Information was extracted from 209,628 birth records. We used multivariate logistic regression to assess the effect of each independent variable on Apgar score less than seven at one minute and Apgar score less than seven at five minutes.

Results: Low birth weight, prematurity and community development were found to be strong predictors of morbidity. Maternal education showed strong negative correlation with both Apgar scores. The negative correlations between maternal schooling and Apgar scores were observed after prenatal care, parity and maternal age were included in the model. Unmeasured proximate factors may thus be the true source of disparity between educational groups. Children of very young adolescent mothers had lower Apgar scores at one minute (but not at five minutes) than those born to mothers 15 to 19. Parity one or higher was associated with decreased odds of low Apgar scores. Cesarean section and operative delivery were associated with higher odds of early infant morbidity.

Conclusion: Education may allow mothers to have better care in the peripartum period. More educated mothers may be more likely to recognize certain morbidities through the pregnancy period and the monitoring of such morbidities yields better infant outcomes. Also, having less than seven prenatal care visits was found to predict early infant morbidity and one way to increase the use of such services is to focus on aspects of care that may lead to easier accessibility and continuity of prenatal care. Physicians should inform mothers about the risks associated with high number of children for a next infant and also about the risks for the infant associated with unnecessary cesarean sections. Special attention should be paid to adolescent mothers, since much of their increased risk is likely to be minimized by counseling.

Background

Early infant morbidities may produce adverse outcomes

in subsequent life. Perinatal conditions, which include predominantly neonatal mortality and also morbidity

account for 6.2% of the global burden of death, sickness and disability, as measured in DALYs (Disability-Adjusted Life Years) third only to lower respiratory tract and HIV infections among all causes of DALY loss. This proportion of DALY is even higher among the poorest in developing countries [1].

Among the most common causes associated with neonatal mortality and long term morbidity that are potentially preventable are birth asphyxia and birth trauma. Of all newborn infants, 3 to 5% require some kind of resuscitation at birth. Estimations based on data from Europe show that half of these infants die and 75 to 100% of those who survive seem to later develop major neurodevelopmental sequelae [2]. We can infer that the burden of asphyxia may be even higher for developing countries. It is estimated that, worldwide, adverse outcomes could be improved for as many as one million neonates a year by means of intrapartum measures to reduce asphyxia and appropriate timely resuscitation of the newborn who fails to breathe at birth [1].

The Apgar score is the traditional index for asphyxia [3], even though it is well recognized that a low Apgar score does not suggest any specific etiology [4]. It is a convenient and appropriate measure of newborn wellbeing. It is an indicator of cardiorespiratory depression, neurologic depression and need for resuscitative efforts [3]. It also constitutes a bioindicator appropriate for demographic research. For Crimmins and Seeman [5] an appropriate measure should represent the physiological status of major regulatory systems and processes (e.g., impaired onset of respiration) through which demographic and socioeconomic variables can work to affect health (e.g., by making resuscitation a more widely spread procedure by capacitating a higher number of physicians in a certain community).

The one-minute and the five-minute Apgar scores have value in predicting infant morbidity, the five-minute score being found to be the better predictor [6]. For full term newborns, diagnosis of cerebral palsy, seizures, epilepsy and mental retardation were found to be significantly associated with Apgar scores below seven at five minutes [7,8]. The use of low Apgar scores as predictor of later morbidities in low birth weight infants is controversial though [9,10].

Apgar scores at ten minutes of life were found to be one of the most powerful predictors of the long-term adverse outcome in severely asphyxiated infants [11], more predictive than one or five minute scores. This is in accordance with findings that irreversible injury to the brain occurs after 12 minutes of total asphyxia [12]. Studies have shown that five and ten-minute Apgar scores are sub-

stantially correlated and in this case low Apgar scores at five minutes can be seen as a proxy for low Apgar scores at ten minutes, and may be indicative of a more permanent morbidity. Misra et al [13] found that mortality and poor neurological and developmental outcome inversely correlated with both five and ten-minute scores, in full term neonates. Blackman [14] found that an Apgar score at five minutes below seven accompanied by seizures significantly predicted greater developmental dysfunction at 30 months of age. In Moster et al [15] Apgar scores at five minutes lower than seven combined with early signs of cerebral palsy significantly predicted a variety of neurodevelopmental impairments and learning difficulties in children 8 to 13 years of age. Apgar scores below seven at five minutes were even found to be associated with autism [16]. Low Apgar scores at one and five minutes have been associated with hearing impairments diagnosed in very early infancy [17,18]. Therefore, low Apgar scores have repeatedly been found to be associated with several morbidities. As such, it can be seen as a measure of compromise of the infant and it may be used as a marker of children who may be in need of follow up after hospital discharge in a hope that their outcome may be improved. In terms of interpretation, a score between seven and ten is considered to be normal [19]. In general, infants with an Apgar score below seven require, at least, stimulation and administration of oxygen by face mask [20].

In this article we study determinants described in the literature as most likely to exert an effect on infant morbidity, provided that they were available in our data. We analysed proximate determinants of low Apgar Scores (sex, plurality, mode of delivery, prior losses, gestational age, prenatal care and birth weight), less proximate determinants (parity and maternal age) and distal determinants (race, maternal education and community development) for the 1998-birth cohort, City of São Paulo, Brazil. These determinants are related to the mother, the infant, and the community and may give us a more complete spectrum of risk factors for low Apgar Scores in Brazil, as we explain. Birth weight and gestational age are highly correlated with low Apgar scores [9]. Twin rates of Apgar scores at one and five minutes lower than seven were found to be significantly higher than singleton rates [21]; male infants are known to be more likely to suffer morbidities than girls in the first year of life [22] and in the absence of evidence of gender bias in favour of young boys in Brazil, it is reasonable to expect a worse outcome for male newborns compared to female newborns [23]. Rogers and Graves [24] verified the association between cesarean delivery and low Apgar scores at five minutes, controlling for factors that often make a cesarean section needed (anemia, bleeding, fetal distress, prolonged rupture of membranes and pregnancy-induced hypertension), but the controls did not eliminate the association suggesting a deleterious effect of

cesarean delivery *per se* on Apgar scores. This finding contradicts Levine et al [25]. A mother with a higher number of prior losses is also considered to bear infants with higher risks of death and early morbidities (and probably low Apgar scores), probably due to higher risks of malformation [26]. Regarding prenatal care, a higher number of prenatal visits was found to be significantly associated with better outcomes in neonatal morbidity, birth weight, maternal weight gain, and Apgar scores at one and five minutes [27]. Race is considered in the analysis, since black infants usually experience much worse health status compared to whites [28]. Maternal education may lower neonatal mortality since educated mothers are less likely to accept fatalist explanations and are more likely to manipulate modern medical systems than less educated mothers [29]. Also, maternal education may be seen partially as a surrogate for household income, which negatively affects morbidity. Higher parities (four or higher previous live births) and nulliparities are considered to exert extra risks for birth outcomes and they are likely to reflect deviance from the normal uterine function. Also, high parity can be seen as a marker for low social status and income which affects infant death [30] and is possibly capturing effects of closely spaced births known to be deleterious to infant health and survival [31]. Regarding maternal age, various socioeconomic disadvantages and suboptimal health outcomes are associated with adolescent pregnancy, such as insufficient education, limited career and job opportunities and poor conditions for effective parenting [32]. Women age 35 and older are also at higher risk for chromosomal abnormalities and other factors associated with higher risks of neonatal morbidity. Rogers and Graves [24], Connolly et al [32] and Chan and Lao [33], found that maternal age was not associated with Apgar scores, but the full spectrum of ages was not considered, or the categories were very broadly defined, with the exception of Rogers and Graves [24]. Finally, the community where the mother resides may affect infant health since it may influence attitudes and behavior. Some characteristics may influence more directly birth outcomes, such as the availability of health services and environmental pollution [34].

Methods

We used information from the SINASC (Information System on Live Births) from the 1998-birth cohort whose mother's place of residence in 1998 was the City of São Paulo. Information was extracted from medical records. Newborns with Apgar scores at one minute below seven were categorized as having low Apgar scores and the remaining infants were considered the reference category. Infants with a missing value for the one-minute score were excluded from the analysis (9,333 infants or 4.5% of the total infants). From the 200,295 infants with a coded one-minute score, 8.0% had low scores (16,052 infants). The

same categorization was used for Apgar scores at five minutes. A slightly lower percentage had missing values for the five-minute score (9,038 infants or 4.3% of the total infants) compared to the one-minute score and from those with recorded Apgar score at five minutes, 1.3% had low scores (2,612 out of 200,590 infants). For the analysis of data we used the STATA 6 software.

Variable Constructs

The outcome variable is whether or not an infant had an Apgar score below seven at one minute or not and whether or not an infant had an Apgar score below seven at five minutes.

Explanatory variables were classified in proximate determinants (birth weight, gestational age, prenatal care, sex, plurality, prior losses and mode of delivery), less proximate determinants (parity and maternal age) and distal determinants (race, maternal education and community development). The ways in which distal determinants are expected to affect more proximate determinants are displayed in Figure 1.

Birth weight was categorized into ten groups (less than 1000 g, 1000 to 1499 g, 1500 to 1999 g, 2000 to 2499 g; 2500 to 2999 g, 3000 to 3499 g, 3500 to 3999 g, 4000 to 4499 g, 4500 g or higher, and missing birth weight). Categories of gestational age were taken as existent in the database: '27 weeks or less', '28 to 36 weeks', '37 to 41 weeks', and '42 weeks or more' and missing. Infants were also categorized according to whether they were singleton births, non-singleton births or this category was missing. Infants were also classified based on whether the delivery was normal; a cesarean; other (primarily forceps); and for unknown mode of delivery. The number of prenatal-care visits was classified based on the existing categories: no visits, 1 to 6 visits, 7 or more visits and unknown number of visits.

Finally, the number of stillbirths and abortions were considered together in a category called "prior losses" and we created four categories: no prior loss, one prior loss, more than one prior loss; and missing information on prior loss.

Maternal age was categorized into consecutive five-year age groups from 15 upwards and a first category to 11 to 14, to estimate the effect of very young maternal age on infant morbidity. The last category was 40 and over; and finally an additional category for missing age. In regard to parity, we categorized it as zero parity; parity one; parity two or three; parity four or higher; and missing parity.

In categorizing race, since whites are historically the most affluent group in Brazil, and because among the non-

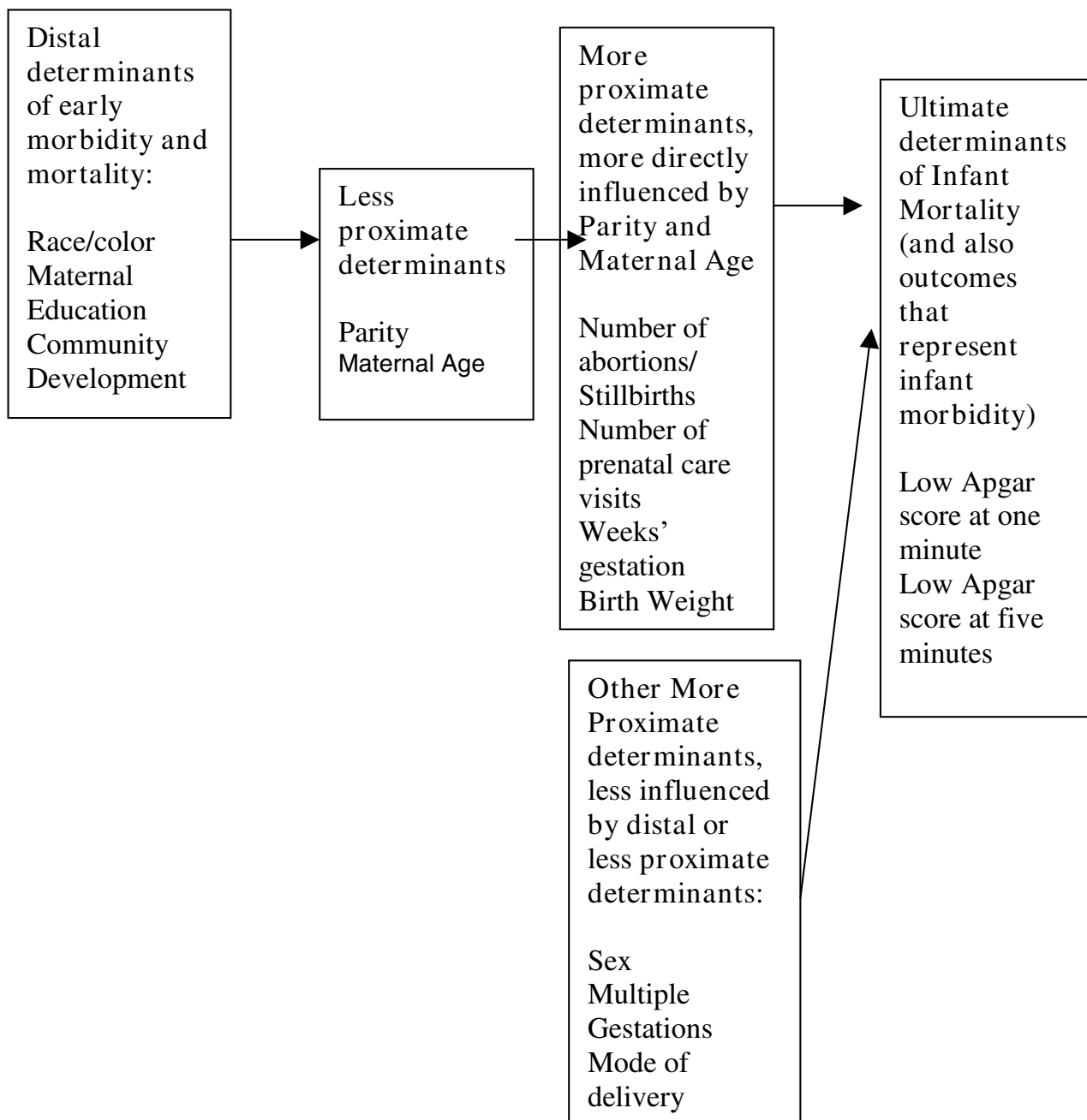


Figure 1
Schematic representation of the modified Mosley-Chen framework

white, 97% are mixed race or black, we defined two categories: "white" and "non-white" and "missing" (67% of all infants). For maternal education the categories were: illiterate; incomplete elementary education; complete elementary education; secondary school; college and an

additional category for missing. Finally, information at the community (or district) level exists for each of the 96 districts in the City of São Paulo. To capture community effects, we created an indicator variable of development for each district and used the method of principal compo-

nents' analysis to weight different district level indicators [35–37]. The method applied here summarized the district-level information on 18 variables, including average educational attainment of the household head, average household income, average access to health services and other facilities, in each district, among others. The technique created a set of mutually uncorrelated components of the data. Intuitively, the first principal component is the linear index that captures the most common variation among the components obtained [35]. We used STATA's 6 factor command and specified the principal components' option within the command.

All community indicator variables were based on the 1991 population census, 1996 population counts, and other district level information, such as the number of school enrolments and unmet need for services such as health care centers in each district. Most indicators are summarized in an index developed for each district called "Index of Social Exclusion/Inclusion" [38,39]. The interpretation of each index is that the higher its value, the higher the average degree of 'social inclusion' of its population into the society, i.e., the better off the population of district is, in comparison to all other districts. Therefore, the interpretation is quite intuitive – the higher, the better. For some variables, though, we only had rates or percentages or even absolute numbers.

The first principal component explained 43.2% of the variation in these 18 variables, which is a substantial percentage. The first component serves as a reasonable overall index and it correlated highly and positively with the IEX_IN for household head level of schooling (any), average household income, average rate of employment, average number of bedrooms per house, and very highly and negatively with number of persons living in the same household. Also, it correlated highly and positively with percentage of women that are household heads. With the first component, therefore, we have obtained an index that summarizes dimensions of education, employment, income and also household 'crowding', and in some extent, women's autonomy. The higher the index, the better off is the district, in relation to one another. After the index was constructed we sorted the infants by 'district development'. The 40% who scored lowest were categorized as living in a 'district with poor development', the middle 40% as living in a 'district with medium development' and the highest scoring 20% were categorized as living in a 'highly developed district' [35].

Univariate Analysis

As a descriptive analysis, we use the percent distribution of all infants from the 1998-birth cohort according to each determinant studied.

Multivariate Analysis

To obtain an adjusted odds ratio, we used a multivariate logistic regression in order to model the two dichotomous outcomes under study. Because characteristics of mothers and infants from the same community were related, we corrected the standard errors for lack of independence between observations using the Huber/White Sandwich correction, which assumes that observations are independent across clusters but not within clusters (the community of mother's residence at the time of birth) [40]. We used STATA 6 for the regression analysis and selected the cluster option within the logit command. This approach does not change the coefficients but takes into account the clustering in the covariance matrix.

The stars next to the odds ratio values indicate the significance of the Wald test of whether the odds ratio is equal to one [41]. Four stars indicates that the p -values fall below 0.001; three stars indicate that the p -values fall in between 0.001 and 0.009; two stars indicate that the p -values fall in between 0.010 and 0.049; one star indicated the p -values fall in between 0.050 e 0.099.

Four models are presented for low Apgar scores at one minute, and four models are presented for low Apgar scores at five minutes. If the idea of proximate determinants is correct, and they are correctly and exhaustively measured, other factors should not have significant effects once proximate determinants are controlled, since every distal determinant should work through one or more proximate variables. Therefore, the ways in which the inclusion of proximate factors affect coefficients for each distal variable may suggest mediating pathways. The first model of the four is a basic model of more distal determinants of infant early morbidity, as proposed by the Mosley and Chen framework for child survival [34]. The second model includes the community development variable. The third model includes parity and maternal age, considered to be relatively more distal/less proximate than determinants such as birth weight and gestational age, for example. Lastly, the fourth model includes the most proximate determinants.

Results

Description of Study Population

As a brief description, most infants were male, singleton, weighed between 3000 and 3500 grams at birth, were term, and were delivered vaginally (though a very high percentage of infants, 46.2%, were delivered by cesarean section). Most infants who had race/color recorded were white, but 66.3% of the infants did not have this information recorded. Most women did not have any prior losses, had more than seven prenatal care visits (but the percentage is not overwhelming since 32.4% of women had less than 7 visits), delivered their first child, were in the age

Table 1: Univariate description of infants with recorded Apgar scores at one and at five minutes

Variable	Categories	Percentage	Variable	Categories	Percentage
Infant's Sex	Male	51.0	Birth Weight (grams)	999 or less	0.4
	Female	49.0		1000 to 1499	0.7
	Missing	0.0		1500 to 1999	1.6
Plurality	Singleton	97.2		2000 to 2499	5.9
	Twins/Higher order	1.9		2500 to 2999	24.8
	Missing	0.9		3000 to 3499	41.7
Delivery Mode	Normal	49.2		3500 to 3999	20.4
	Cesarean	46.2		4000 to 4499	3.8
	Other	4.0		4500 or higher	0.5
	Missing	0.6		Missing	0.2
Prior Losses	None	58.6	Maternal Age	11 to 14	0.4
	One	9.6		15 to 19	16.7
	Two or More	2.9		20 to 24	28.7
	Missing	28.9		25 to 29	25.9
Weeks' Gestation	27 or less	0.5		30 to 34	18.3
	28 to 36	5.2	35 to 39	8.0	
	37 to 41	88.4	40 or higher	1.9	
	42 or more	1.1	Missing	0.1	
	Missing	4.8	Race/Color	White	23.3
Prenatal Visits	None	2.0		Non-white	10.4
	1 to 6 visits	30.4		Missing	66.3
	7 visits or more	35.9	Maternal Education	No schooling	1.4
	Missing	31.7		Elementary, incomplete	35.6
Parity	None	35.9		Elementary, complete	17.5
	One	24.9		Secondary	17.8
	Two or three	16.7	College	7.9	
	Four or More	4.1	Missing	19.8	
	Missing	18.4	Community Development	Low	40.0
		Medium		40.0	
		High		20.0	

Source: DATASUS <http://www.datasus.gov.br>, 2000

group 20 to 24 and had only incomplete elementary school. The educational level of these mothers may be considered low: even though 79.1% of all mothers were at least 20 years old, an age by which every person, theoretically, could have finished secondary school, 37% of all mothers were illiterate or did not have an elementary school degree.

Distal Determinants

Being a non-white newborn was significantly associated with low one minute score, but not with five minute scores, in all four models. The findings for the one-minute Apgar score show a consistent race/colour effect independent of proximate factors related to the newborn and the mother. The odds of a non-white infant having a low Apgar score at one minute were 8.3% higher than for a white infant at one minute in the final model (OR = 1.083, $p < 0.05$). In our final model, infants with missing information on race/color had a higher odds of low one-

minute scores (OR = 1.065, $p < 0.05$), but their odds were 10% lower at five minutes even though the finding was not significant.

Maternal schooling reduced the odds of low Apgar scores at one and at five minutes. The association was strong, and sustained, from Models 1 to 4. The effect is not evident though in case of illiterate mothers, indicating that illiteracy did not increase the risk of low scores, compared to mothers with incomplete elementary schooling. Model 4 indicated that infants of mothers with complete elementary education, secondary education, and college were progressively at lower odds of having low one-minute and five-minute Apgar scores than infants of mothers with incomplete elementary school as indicated by the positive sign of the coefficients and high levels of significance of these individual findings. Infants with unrecorded level of schooling also had lower odds of low Apgar scores at one and five minutes. The size of the odds ratio suggests that

Table 2: Adjusted odds ratios for low Apgar score at one minute

Variable	Categories	Adjusted Odds Ratios			
		Model 1	Model 2	Model 3	Model 4
Race/ Color (refer: white)	Non-white	1,059*	1,057*	1,071**	1,083**
	Missing	1,074**	1,075**	1,082***	1,065**
Maternal Education (ref: el, incomplete)	No schooling	0,998	0,985	1,006	1,059
	Elementary, complete	0,897***	0,893***	0,868***	0,863***
	Secondary	0,871***	0,871***	0,808***	0,769***
	College	0,555***	0,557***	0,490**	0,453***
	Missing	0,891**	0,884**	0,867***	0,862***
Community Development (refer: high)	Low		1,039	1,057*	1,090***
	Medium		1,001	1,030	1,097**
Parity (refer: none)	One			0,668***	0,739***
	Two or three			0,621***	0,697***
	Four or More			0,667**	0,755***
	Missing			0,759**	0,859**
Maternal Age (refer: 20 to 24)	11 to 14			1,239**	1,063
	15 to 19			0,985	0,955*
	25 to 29			1,024	1,005
	30 to 34			1,134***	1,048†
	35 to 39			1,279***	1,111***
	40 or higher			1,626***	1,335***
	Missing			2,460***	1,846**
Infant's Sex (refer: male)	Female				0,854***
Plurality (ref: singleton)	Twins/Higher order				0,962
	Missing				0,804***
	Cesarean				1,471***
Delivery Mode (refer: normal)	Other				3,313***
	Missing				1,514***
Prior Losses (ref: no prior loss)	One				1,035
	Two or More				1,065
	Missing				0,855***
Weeks' Gestation (refer: 37–41)	27 or less				3,313***
	28 to 36				1,859***
	42 or more				1,587***
	Missing				1,043
Prenatal Visits (ref: 7 or more)	None				1,379
	1 to 6 visits				1,039***
	Missing				1,077
Birth Weight (in grams) (refer: 3000 to 3500)	999 or less				41,31**
	1000 to 1499				10,45***
	1500 to 1999				4,693***
	2000 to 2499				1,923***
	2500 to 2999				1,135***
	3000 to 3499				1,090**
	4000 to 4499				1,448***
	4500 or higher				1,998***
	Missing				4,112***

*p-value <0.1 **p-value <0.05 ***p-value <0.01 ****p-value <0.001 Source: DATASUS <http://www.datasus.gov.br>, 2000

women with lower levels of schooling were more likely to be represented in this category.

The community development variable made virtually no difference in the size and significance of the two other distal determinants of Apgar scores. This finding is consistent

with the idea that characteristics related to the mothers were more likely to be related to infant outcomes than community characteristics. But the introduction of the variables improved the predictive power of the model, as the likelihood ratio test was significant (*p-value* < 0.0001) in testing the model with the two variables versus the

model without the variable. Living in a community with low (but not medium) degree of development as compared to living in a highest developed community significantly increased the odds of low one-minute scores in Model 3 (OR = 1.057, $p < 0.1$), but in the model controlling for more proximate factors (Model 4), living in a medium and least developed communities significantly increased the odds of low one-minute score (OR = 1.097, $p < 0.05$; OR = 1.090, $p < 0.01$, respectively). Living in a community with the lowest development as compared to living in a community with the highest development increased the odds of low five-minute scores by 12 percent (OR = 1.119, $p < 0.1$), whereas the effect of living in a community with medium development disappeared in the presence of more proximate factors.

Less Proximate Determinants

As a general rule, not being the first live born child was associated with a decreased odds of low Apgar scores, as seen in Models 3 and 4. Third or fourth children had odds of low Apgar scores at one and five minutes 30% and 19% lower, respectively, than for their first-children counterparts (OR = 0.697, $p < 0.001$ and OR = 0.809, $p < 0.01$, respectively). Infants with no information on number of siblings also had a lower odds of low scores. We may infer that infants with more siblings were more likely not to have this information recorded. In this population there is just a subtle indication that higher parity is less advantageous than other categories of multiparity, as seen by the change in the odds ratio and its significance from Model 3 to 4 for low Apgar score at five minutes (in Model 3, OR = 0.778, $p < 0.05$; and in Model 4 OR = 0.824, $p < 0.1$). Without controlling for interpregnancy interval, however, we cannot affirm whether or not this is a net effect of grand-multiparity.

The results for maternal age should be examined carefully. Models 3 and 4 suggest that being 11 to 14 or 30 years or older increase the odds of low one-minute score. After controlling for more proximate determinants, the apparent disadvantage of young teenage motherhood disappeared and, indeed, having a child at age 15 to 19 significantly *decreased* the odds of low one-minute score by 4.5 percent (OR = 0.955, $p < 0.1$). For mothers 30 to 34, the inclusion of proximate factors in the model also changed the coefficient and infants of these mothers had a higher odds of low one-minute score in the final model, even though it was no significant (OR = 1.134, $p < 0.001$, and in Model 4 OR = 1.048, $p > 0.099$). The deleterious effect remained, however, for mothers above 34 years of age, but the strength of the association was reduced. Infants of mothers 11 to 19 were not at increased odds of low five-minute scores in either model. Infants of older mothers (35 and above) had higher odds of low five-minute scores, before the inclusion of more proximate

determinants. After controlling for those, the advanced maternal age effect completely disappeared. Also, having no maternal age recorded increased the odds of low one and five-minute scores and the effect persisted in both models.

More Proximate Determinants

The odds of low Apgar scores at one and five minutes for female infants were 15 and 25% lower, respectively than the odds of low Apgar scores for male infants (OR = 0.854, $p < 0.001$ and OR = 0.751, $p < 0.001$, respectively). This finding is in accordance with the idea that boys are frailer than girls are at birth.

The odds of low Apgar score at one and five minutes for multiple births were, respectively, 4 and 28% lower than for their singleton counterparts, but this finding was not significant for one minute scores (OR = 0.962, $p > 0.099$ and OR = 0.751, $p < 0.001$, respectively). This is not a suggestion that multiple births exert a protective effect on Apgar scores. Infants of multiple pregnancies tend to be pre-term and immature and are at higher risk of several morbidities. But, after controlling for characteristics that make a non-singleton infant a high-risk infant, such as birth weight and weeks' gestation, their apparent disadvantage disappeared and they were expected to have a *better* outcome. Infants with unrecorded information had a reduced odds of low scores though the finding was not significant at five minutes ($p > 0.099$). This seems to suggest in the case of more difficult deliveries (such as the delivery of twins or triplets) such information is more likely to remain unrecorded. This interpretation makes sense, since the physician may be overwhelmed with such a delivery and less likely to fill out the records.

Delivering by cesarean increased the odds of low scores at one and five minutes by approximately 1.5 times (OR = 1.471, $p < 0.001$) and 1.4 times (OR = 1.365, $p < 0.001$), respectively compared to a normal/vaginal delivery. These figures were 3.3 (OR = 3.313, $p < 0.001$) and 2.9 (OR = 2.855, $p < 0.001$) in case of forceps delivery (or other method).

These findings were not unexpected. Analgesia, for example, is required for both procedures and is likely to reduce the score. Also, medical problems of the mother may require a non-vaginal delivery and may be in the causative pathway to reduce the score. Unfortunately, without controlling for whether or not a c-section was elective or for other maternal morbidities, we cannot determine whether there are risks associated with the procedures themselves or if morbidities that make a cesarean or a forceps delivery more likely are in the causative pathway, even though the high cesarean section rate suggests that many c-sections

are indeed elective. Finally, infants with unrecorded information on delivery mode had higher odds of low scores.

The only significant finding regarding prior losses was that for mothers with missing numbers of prior losses, the infants had lower odds of low one-minute scores (OR = 0.855, $p < 0.001$).

Infants of mothers who had no prenatal care visits had an odds of low one and five minute score that were 38% (OR = 1.379, $p < 0.001$) and 54% higher (OR = 1.543, $p < 0.001$), respectively, than for infants of women with 7 or more prenatal care visits. Infants of mothers who had 1 to 6 prenatal care visits also had a higher odds of low scores at both times, but the result was not significant. At one and at five minutes, having no information on the number of visits increased the odds of low one-minute score by 8% (OR = 1.077, $p < 0.05$). The finding was significant at one minute but not significant at five minutes (OR = 1.085, $p > 0.099$). This suggests that women with fewer visits were slightly more likely to be represented in the group.

The very preterm newborns (less than 28 weeks' gestation) had odds of low scores at one and five minutes that were 3.3 times (OR = 3.313, $p < 0.001$) and 5.1 times higher (OR = 5.053, $p < 0.001$), respectively, than for their term counterparts. Less preterm (28 to 36 weeks) and post-term (42 weeks or higher) newborns also had higher odds of low scores at one and five minutes. Infants with missing information on weeks' gestation did not have a significantly higher odds of a low-one minute score but their odds were 74% higher at five minutes (OR = 1.74, $p < 0.001$), which suggests that non-term infants were more likely to be represented in this group.

The optimum birth weight range for this population, that in which the odds of Apgar scores at one and five minutes was lowest, was 3000 to 3499 grams. Infants at birth weights below 2000 grams were particularly at high-risk of low scores at one and five minutes. If the infant had a missing birth weight (at one or five minutes), he or she had substantially higher odds of low scores. These infants seemed to come from lower birth weight ranges. Even though the missing category is likely to be a composition of various birth weight ranges, almost surely, this category is biased towards low weights.

Discussion

In our study, low birth weight and prematurity were found to be strong predictors of morbidity. These results are consistent with findings in the literature. The association between low Apgar scores and low birth weight and low gestational age, for preterm births, was found by Hegyi et al [42], in a population based study conducted in

New Jersey. De Hart [9] also found a strong association between preterm birth and low birth weight, for infants with birth weight below 2500 grams in a hospital in Delaware.

We have observed that the only significant finding regarding prior losses was that for mothers with missing numbers of prior losses, the infants had lower odds of low one-minute scores. Maybe, mothers with no prior losses did not have this information recorded, which is a similar effect of categorizing women of non-stated parity as childless women [43].

Non-white color/race was found to be correlated with low Apgar scores. Coloured infants were probably more likely to be assigned low scores at one minute but not at five minutes since a black infant is usually not completely pink at birth [44]. In our study, this is likely to be the case, since the effect was noticed only at one minute.

Maternal education showed a strong negative correlation with both Apgar scores, which was consistent with results in Grjibovski et al [45]. The authors conducted a study in Severodvinsk, north-west Russia. This suggests that education may allow mothers to have a better care in the peripartum period, perhaps due to their higher income, a variable that unfortunately could not be directly measured here. More educated mothers may also be more likely to recognize certain morbidities through the pregnancy period and the monitoring of such morbidities most certainly yields better immediate infant outcomes. The fact that after including more proximate factors in the model the effect of education on the odds of low scores remained quite the same suggests that other proximate factors not available here may be the true source of disparity between educational groups. Examples would be time of initiation of prenatal care [46–48], quality of prenatal care, or certain maternal morbidities more common in later stages of the reproductive career, such as diabetes or maternal hypertension.

Infants of older mothers fared worse in terms of morbidity, which is not an unexpected finding. After controlling for factors that make old age at motherhood likely to be a risk factor, the net age effect was almost nullified (five-minutes) or substantially reduced (one-minute). Compared to an older mother, a younger mother may be less likely to attend prenatal visits [49]. One reason is that their pregnancies, as a group, are more likely to be mistimed. They may delay the first visit, for instance, if they are not married. After controlling for prenatal care, the differential effect of age that was due to prenatal care will disappear. Thinking about older mothers, they may be more likely to be delivered by cesarean [50]. But after controlling for the procedure, the effect of older age on Apgar

scores is diminished. In case of adolescent mothers it is also interesting to note that children of very young adolescent mothers (11 to 14) had lower Apgar scores at one minute (but not at five minutes) than those born to mothers 15 to 19, consistent with findings in the literature that children of still growing adolescents are likely to have worse outcomes than adolescents with completed maturation [51].

Parity one or higher was associated with decreased odds of low Apgar scores at one and five minutes, which was in agreement with findings for a Teaching Hospital in Uganda, where the authors found that primiparity was an independent risk factor for low Apgar scores [52]. Unfortunately, with the available data for our study, we could not sort out the effect of birth spacing from the effect of parity.

Finally, cesarean section and operative delivery were associated with higher odds of early infant morbidity as it was shown in Rogers and Graves [24].

Our study is important and generalizable, since it is population-based. Does not suffer problems of selection bias in recruiting individuals for study, since uses data from the entire population of infants in a given year from the biggest city in Brazil. Probably, a new major contribution, is the fact that we verified that children of college mothers were much less likely to have low Apgar scores. This is probably a result of the increased statistical power of our study due to large sample size since the percentage of college educated mothers is small in this population (less than 8%). To our knowledge, this association has not been verified before in Brazil. Nevertheless, this analysis has limitations. We were not able to draw a comprehensive picture of the household and parental determinants of newborn well being and the interpretation of the community development indicator is confused by the possibility of ecologic fallacy, since we could not study fully how determinants of household wellness behave in the presence of controls for community development. The only inference we can make is that at a population level infants from more developed communities do better in terms of early wellbeing and survival even in the presence of controls for maternal education. A first feasible effort would be the inclusion of occupation of father and mother in the birth records, since they are already routinely collected in the death records. In the literature, paternal education has been found to be associated with perinatal mortality [53], and has not been ruled out as one of the determinants of infant mortality, though its effect has been consistently found not to be as strong as that of maternal education [29]. To the extent that paternal education would help us, we missed an indicator that could have allowed a better understanding of such rela-

tionship. These data are important since studies in Brazil have shown that support from spouse is an important predictor of breastfeeding intentions (for example, [54]). Higher paternal education may well be associated with such an attitude and may serve as a significant predictor of infants' health.

Another serious drawback in our study is the high percentage of missing information for variables evaluated as possible determinants of low Apgar scores. It was particularly high for prior losses (28.9%), number of prenatal visits (31.7%), parity (18.4%), maternal education (19.8%) and extremely high concerning race (66.3%). In essence, missing values can lead to erroneous conclusions about the data. Our approach consisted in including individuals with missing information on independent variables, which increased the power of our analysis. However, unknown real values for these variables may indeed affect the model estimations in unknown directions, since each category of missing values is likely to be a composition or a 'mix' of different values, for each variable. As an extreme example, if there were a systematic misclassification from mothers with no schooling towards the missing category, our conclusions about the null effect of illiteracy on low Apgar scores would be incorrect.

Perhaps the most important next step is to assess the validity and reliability of information collected in less developed states of Brazil. São Paulo has excellent data quality compared to most other cities in Brazil. A very quick look at information obtained from North and Northeast birth record files has revealed an unusually high number of infants with Apgar scores of zero. This is most likely to be an error in coding the information (infants with no information on Apgar are recorded as having Apgar zero). This is probably a problem in the system data entry, where the staff is not properly trained and indiscriminately entered the '0' for missing. Problems related to data quality have to be assessed and further addressed in order to allow verification of patterns and differentials countrywide.

Conclusions

There are several ways to improve the health of the infants in Brazil. Having less than seven prenatal care visits was found to independently predict early infant morbidity. One way to increase the use of such services is to focus on specific aspects of care that may lead to easier accessibility and continuity of prenatal care, especially for disadvantaged mothers who are likely to depend on the public health system for care. Research has shown that low income women value several aspects of primary care, such as: accessibility, physician-patient relationship, comprehensive scope of care (including aspects such as compassion of the care provider and extra-hours care) and

Table 3: Adjusted odds ratios for low Apgar score at five minutes

Variable	Categories	Adjusted Odds Ratios			
		Model 1	Model 2	Model 3	Model 4
Race/ Color (refer: white)	Non-white	0,958	0,947	0,957	0,914
	Missing	0,934	0,940	0,946	0,899
Maternal Education (ref: el, incomplete)	No schooling	0,901	0,907	0,913	1,005
	Elementary, complete	0,839***	0,829***	0,814***	0,829**
	Secondary	0,824***	0,827***	0,795***	0,754***
	College	0,433***	0,430***	0,403***	0,381***
	Missing	0,879***	0,871*	0,856**	0,802***
Community Development (refer: high)	Low		0,998	1,016	1,120*
	Medium		0,935	0,943	0,985
Parity (refer: none)	One			0,735***	0,825***
	Two or three			0,728***	0,809***
	Four or More			0,778**	0,824*
	Missing			0,831**	0,798***
Maternal Age (ref: 20 to 24)	11 to 14			0,976	0,700
	15 to 19			1,092†	1,000
	25 to 29			0,952	0,970
	30 to 34			1,092†	1,012
	35 to 39			1,182*	0,955
	40 or higher			1,631***	1,190†
	Missing			6,495***	4,276***
Infant's Sex (refer: male)	Female				0,751***
Plurality (refer: singleton)	Twins/Higher order				0,718***
	Missing				0,668†
	Cesarean				1,365***
Delivery Mode (refer: normal)	Other				2,855***
	Missing				1,592*
Prior Losses (ref: no prior loss)	One				1,101
	Two or More				0,974
	Missing				0,976
Weeks' Gestation (refer: 377–41)	27 or less				5,094***
	28 to 36				2,255***
	42 or more				1,505*
	Missing				1,740***
Prenatal Visits (ref: 7 or more)	None				1,543***
	1 to 6 visits				1,083†
	Missing				1,085†
Birth Weight (in grams) (refer: 3000 to 3500)	999 or less				57,34***
	1000 to 1499				16,66***
	1500 to 1999				7,463***
	2000 to 2499				2,939***
	2500 to 2999				1,267***
	3000 to 3499				1,135***
	4000 to 4499				1,280**
	4500 or higher				3,294**
	Missing				17,18***

*p-value <0.1 **p-value <0.05 ***p-value <0.01 ****p-value <0.001 Source: DATASUS <http://www.datasus.gov.br>, 2000

continuity with a single physician [55]. In Brazil, public health is universal, but health posts and hospitals are frequently undersupplied and understaffed. Even though we recognize these problems there is an urgent need to address them. With the demographic transition and the aging of the Brazilian population and low levels of fertil-

ity, there is a unique window of opportunity now to focus on maternal health during pregnancy and immediate post-partum, and to implement efforts to ensure a healthy pregnancy and delivery and care of the infant, with relatively modest resources.

In providing care for mothers at reproductive ages, physicians should inform them about the risks associated with high number of children for a next infant. They should also inform mothers about the risks for the infant associated with unnecessary cesarean sections. In Brazil, ethnographic studies have shown that rich women are more likely to have cesarean sections, reflecting the notion that medical intervention during birth represents superior care. Many poor women are now requesting c-sections without any knowledge about the risks that such a procedure may pose to the newborn [56]. Finally, special attention should be paid to adolescent mothers, since much of the risk associated with adolescence pregnancy is likely to be minimized by the right counseling. If we accept the idea that younger mothers are less likely to have planned the pregnancy and are less likely to breastfeed: breastfeeding counseling for unwanted pregnancies is a way to address the issue and improve health outcomes. There is evidence in the literature that poor mothers may be more willing to accept an unwanted pregnancy than richer and more socially advantaged ones and therefore, the right medical advice may be particularly effective for those mothers [57].

Childhood is a unique period of life. Forrest et al [58] have pointed out that developmental change is an essential characteristic of childhood. The health of the children depends in large measure on the success of their cognitive, emotional and physical growth and development; and infancy is a very important starting point of a healthy childhood. Long term morbidity that begins in childhood has a disproportionate effect on health over the life span. In the United States, one third of all disability years are attributable to conditions with onset in childhood [58]. Ignoring or minimizing attention to focus on health services that target the wellbeing of infants and children is both shortsighted and costly [58]. We have no doubt that the risk of neglecting the health of children in Brazil is even more dangerous than it is for developed countries. As a country with problems of strong social inequalities, minimizing health disparities among all infants and children in Brazil can assure a more equal access to subsequent life opportunities.

Competing interests

None.

Authors' contributions

This manuscript is part of CM PhD thesis. CM conceived of the study, performed the statistical analysis and drafted the manuscript. KH advised the student during all the process of development of the thesis. Both authors read and approved the final manuscript.

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