ISSN 0300-5771 (PRINT)
ISSN 1464-3685 (ONLINE)

International Journal of Epidemiology

Official Journal of the International Epidemiological Association

Volume 48 Supplement 1 April 2019

https://academic.oup.com/ije

Applying an equity lens to time trends in maternal and child health in Brazil: 1982–2015 plus Cohort profile up-date: The 1993 Pelotas (Brazil) Birth Cohort follow-up at 22 years

Guest Editor: Antônio Augusto Moura da Silva

IEA

OXFORD
UNIVERSITY PRESS

International Journal of Epidemiology, 2019, i37–i45
doi: 10.1093/ije/dyy211
Supplement Article

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Antenatal care and caesarean sections: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Aluisio JD Barros ,[1] **Cesar G Victora** ,[1]* **Bernardo L Horta** ,[1] **Fernando C Wehrmeister** ,[1] **Diego Bassani** ,[2] **Mariângela F Silveira** ,[1,3] **Leonardo P Santos** ,[1] **Cauane Blumenberg** ,[1] **Fernando C Barros** [1,4] **and the Pelotas Cohorts Study Group****

[1]Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas Brazil, [2]Centre for Global Child Health, University of Toronto, Toronto, ON, Canada, [3]Maternal and Child Health Department and Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil and [4]Postgraduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

*Corresponding author. Postgraduate Program in Epidemiology, Federal University of Pelotas, R. Mal. Deodoro 1160 3o. piso, 96020-220 Pelotas, RS, Brazil. E-mail: cvictora@gmail.com
**Members listed at end of article.

Editorial decision 30 August 2018; Accepted 8 October 2018

Abstract

Background: Antenatal care and correctly indicated caesarean section can positively impact on health outcomes of the mother and newborn. Our objective was to describe how coverage and inequalities for these interventions changed from 1982 to 2015 in Pelotas, Brazil.

Methods: Using perinatal data from the 1982, 1993, 2004 and 2015 Pelotas birth cohorts, we assessed antenatal care coverage and caesarean section rates over time. Antenatal care indicators included the median number of visits, the prevalence of mothers attending at least six visits and the proportion who started antenatal care in the first trimester of pregnancy and attended at least six visits. We described these outcomes according to income quintiles and maternal skin colour, to identify inequalities. We described overall, private sector and public sector caesarean section rates. Differences in prevalence were tested using chi-square testing and median differences using Kruskal-Wallis testing.

Results: From 1982 to 2015, the median number of antenatal care visits and the prevalence of mothers attending at least six visits increased in all income quintiles and skin colour groups. Inequalities were reduced, but not eliminated. The overall proportion of caesarean births increased from 27.6% in 1982 to 65.1% in 2015, when 93.9% of the births in the private sector were by caesarean section. Absolute income-related inequalities in caesarean sections increased over time.

Conclusions: Special attention should be given to the antenatal care of poor and Black women in order to reduce inequalities. The explosive increase in caesarean sections requires radical changes in delivery care policies, in order to reverse the current trend.

Key words: Prenatal care, caesarean section, healthcare disparities, cohort studies

Key Messages

- The number of antenatal care visits and the coverage of antenatal care indicators increased in all income quintiles and skin colour groups; however, inequalities are still sizeable.
- There was a marked increase, from 41% in 1982 to 63% in 2015, in the proportion of women with eight or more antenatal visits, which is the current recommendation by the World Health Organization.
- Regarding coverage with six or more antenatal care visits, the gap between women in the richest and poorest quintiles fell from 40% to 16% points between 1982 and 2015.
- Absolute inequalities in caesarean sections—expressed by the difference between the richest and poorest quintiles—increased over time, whereas relative inequalities—expressed as the corresponding ratio—decreased.
- The prevalence of caesarean sections is unacceptably high, being almost universal in the private sector in 2004 and 2015. Radical policies are needed to reverse the observed trend.

Introduction

In 2015, the United Nations proposed a new agenda containing 17 goals to improve the lives of people—the Sustainable Development Goals [SDGs]—to be achieved by 2030.[1] Goal 3 reads 'ensure healthy lives and promote well-being for all people at all ages',[2] and the main specific targets aim to reduce maternal mortality, end preventable deaths of children under 5 years of age and ensure universal coverage of health services. The focus on fighting inequalities is implicit in the 'for all people at all ages' qualifier; unlike the Millennium Development Goals, equity is central to the SDGs.

Antenatal care [ANC] carries an essential set of interventions and actions aimed at reducing maternal and child morbidity and mortality. Quality ANC reduces the risk of maternal morbidity and mortality, and also promotes women's health through the provision of information about risk behaviours and promotion of breastfeeding and contraception.[3] Additionally, ANC can also prevent morbidity and mortality in children through preventive interventions [such as tetanus immunization] and early detection of problems.[4] However, inequalities in the coverage of ANC, most often with lower coverage among the poorer and more vulnerable women, may hinder the impact of ANC on the population as a whole.[5,6]

Delivery by caesarean section is also associated with maternal and newborn survival, as it can be a lifesaving intervention when suitably indicated.[7] In recent decades, however, caesarean section rates have increased in many countries,[8,9] becoming more common than vaginal births in Brazil.[10] When a large number of unnecessary caesarian deliveries are performed, the risks of complication become a concern. A large study on the risks and benefits of caesarean section has concluded that although benefiting deliveries with a breech presentation, the risk of severe maternal and neonatal morbidity and mortality for cephalic presentations was greater than for vaginal delivery. Recent epidemiological studies have linked caesarean section birth with increased risk of several outcomes later in life, such as type 1 diabetes,[11] asthma[12,13] and obesity,[13–15] although the literature is not fully consistent on such associations. Nevertheless, given the possibility of scheduling the delivery [convenient to doctors and to mothers], the absence of pain during delivery and a perception of safety and technological sophistication, caesarean sections are usually much more common among mothers who are richer or private sector clients.[8]

Since 1982, four population-based birth cohorts have been started in Pelotas, a Southern Brazilian city. The 1982,[16] 1993,[17] 2004[18,19] and 2015[20] Pelotas Birth Cohort studies recruited nearly 20 000 individuals, of whom over 15 000 are still being followed up. The study covers a wide range of topics, including morbidity and mortality, growth, development and cognition, and violence. ANC and type of delivery have been extensively studied. Because the cohorts span over 33 years, it is possible to present a broad view of what happened in the country during these years, when Brazil faced significant changes in its health system and in its economy. Using data from four population-based cohort studies, we describe how ANC coverage and proportion of caesarean section among mothers changed over time. We also address changes in inequalities in terms of income and skin colour, according to the number of ANC visits and the frequency of caesarean section.

Methods

Pelotas is a city located in the south of Brazil, with approximately 340 000 inhabitants as of 2015.[21] The Pelotas Birth Cohorts are multipurpose longitudinal studies that follow very similar methodologies. All liveborns from mothers who lived in the urban area of the city, in the years of 1982,[16] 1993[17] 2004[18,19] and 2015[20] were recruited. All maternity hospitals in Pelotas were visited daily during each year in order to invite the mothers to take part in the studies. In the perinatal assessment, mothers were interviewed within 24 h of delivery, and the newborns were examined. The four Pelotas Birth Cohorts enrolled 6011 newborns in 1982, 5304 in 1993, 4287 in 2004 and 4329 in 2015. The recruitment was limited to maternity hospitals since they account for at least 99% of the births. The present analyses focus on the information collected in the perinatal studies. More details about the individual studies can be found in the cohort profiles, previously published.[16,17,19–21]

In the perinatal studies, trained interviewers asked each mother about the pregnancy and birth, including the total number of antenatal care visits and the month of pregnancy in which the first antenatal care visit occurred. In 1982, information on the date of the first ANC visit was only asked for women giving birth from September to December. In 2015, this variable was extracted from the antenatal care cards presented by the women. In addition, mothers were also asked about the type of delivery [vaginal or caesarean] and whether the delivery was funded by the public health system—Sistema Único de Saúde [public sector] —or through a private health insurance or out-of-pocket payment [private sector].

Four ANC indicators were studied: the median number of ANC visits, proportion of mothers attending at least six ANC visits [the proposed minimum by the Brazilian Ministry of Health for the cohort years], antenatal care adequacy according to the Kessner criteria and tproportion of mothers who had at least six ANC visits, starting in the first trimester of pregnancy, as a proxy indicator of ANC quality. Based on this indicator, the proportion of women starting ANC in the first trimester of gestation was lower in 2015 than in 2004 or 1993, and upon closer scrutiny it became evident that health care workers were routinely recording the date of the second visit—when women were returning to the clinic with laboratory examinations—rather than the first visit when the examinations had been ordered by the doctor. Thus, because of poor comparability, this last indicator was not presented for the 2015 cohort. This problem did not affect the information on the total number of visits, which was reported by women during the perinatal interview. The Kessner method classifies antenatal care as adequate when the number of visits is acceptable in relation to gestational age at birth; this method was designed to allow for the fact that shorter gestations are likely to be associated with fewer visits to a provider.[22] This classification is more demanding than the indicator of women with six or more visits; for example, nine or more visits are required to be considered adequate when gestational age equals 36 or more weeks. Finally, we also assessed the proportion of caesarean births in each year.

Two stratifiers were used to analyse inequalities: maternal skin colour and household income. Skin colour was categorized into Black, Brown or White [except for 1982, when it was recorded just as White or non-White]. Assessment was made by the interviewers in 1982 and 1993 and based on self-report in 2004 and 2015. Due to the high level of miscegenation in the Brazilian population, it makes more sense to refer to skin colour rather than ethnicity, as is common in other countries. According to the 2010 census, carried out by the Brazilian Institute for Geography and Statistics [IBGE], 43% of the Brazilian population self-classified as ‘pardos’ [referred to as Brown in this article], mostly an admixture of African and European descendants. National censuses in Brazil have long used this skin colour classification instead of other categorizations. Household income was calculated by summing the income of all household members, and subsequently dividing total income into quintiles.

Differences in the median of ANC visits according to quintiles of household income and maternal skin colour in the four birth cohorts were assessed using the Kruskal-Wallis test. In addition, we used chi-square tests to identify differences in the proportion of caesarean sections and ANC coverage between the four birth cohorts, according to quintiles of household income and maternal skin colour and also according to public or private health sector care [caesarean sections only].

The concentration index and the slope index of inequality were calculated to assess inequalities in ANC visits and caesarean sections according to income, from 1982 to 2015. The concentration index is a relative measure of inequality and uses a similar approach to the Gini index, ordering individuals according to income on the x-axis and plotting ANC visits or caesarean sections on the y-axis. The slope index is an absolute measure of inequality obtained here, using a logistic regression of ANC visits or

Table 1. Median number of antenatal care visits and proportion of women who attended at least 6 antenatal care visits during pregnancy, who attended at least six antenatal visits during pregnancy starting in the first trimester, and who delivered through a caesarean section, for each of the four Pelotas Birth Cohorts [1982, 1993, 2004 and 2015]

Outcomes	Birth cohort year				*P*-value[b]
	1982	1993	2004	2015	
Total number of deliveries	*n* [%]	*n* [%]	*n* [%]	*n* [%]	0.055
Live-born	5914 [98.4]	5249 [99.0]	4231 [98.7]	4275 [98.8]	
Stillbirths	97 [1.6]	55 [1.0]	56 [1.3]	54 [1.2]	
Total	6011 [100.0]	5304 [100.0]	4287 [100.0]	4329 [100.0]	
	Median [IQR]	Median [IQR]	Median [IQR]	Median [IQR]	
Median number of ANC visits	7 [5–9]	8 [5–10]	8 [6–10]	8 [6–10]	<0.001
Total number of ANC visits	*n* [%]	*n* [%]	*n* [%]	*n* [%]	<0.001
0 visits	306 [5.1]	257 [4.9]	81 [2.0]	88 [2.1]	
1-3	657 [11.0]	364 [6.9]	236 [5.8]	170 [4.0]	
4-5	1021 [17.1]	755 [14.3]	488 [11.9]	440 [10.3]	
6-7	1525 [25.5]	1205 [22.8]	927 [22.6]	905 [21.1]	
8+ visits	2474 [41.4]	2711 [51.2]	2374 [57.8]	2683 [62.6]	
Total	5983 [100.0]	5292 [100.0]	4106 [100.0]	4286 [100.0]	
Number of ANC visits starting in the 1st trimester					<0.001
Did not start in the 1sttrimester	1010 [47.3]	1626 [31.3]	1207 [29.5]	–	
1-3	21 [1.0][a]	41 [0.8]	35 [0.9]	–	
4-5	73 [3.4][a]	224 [4.3]	170 [4.2]	–	
6-7	285 [13.4][a]	864 [16.6]	611 [14.9]	–	
8+	743 [34.9][a]	2447 [47.0]	2073 [50.5]	–	
Total	2132 [100.0][a]	5202 [100.0]	4096 [100.0]	–	
Type of delivery					<0.001
C-section	1659 [27.6]	1620 [30.5]	1937 [45.2]	2808 [64.9]	
Vaginal	4352 [72.4]	3684 [69.5]	2350 [54.8]	1520 [35.1]	
Total	6011 [100.0]	5304 [100.0]	4287 [100.0]	4328 [100.0]	
Parity					<0.001
0	2322 [39.3]	1843 [35.1]	1666 [39.3]	2112 [49.4]	
1	1661 [28.1]	1457 [27.8]	1111 [26.3]	1321 [30.9]	
2+	1929 [32.6]	1949 [37.1]	1453 [34.4]	840 [19.7]	
Total	5912 [100.0]	5249 [100.0]	4230 [100.0]	4273 [100.0]	
Maternal age					<0.001
12-19	912 [15.4]	915 [17.4]	800 [18.9]	622 [14.6]	
20-24	1843 [31.2]	1447 [27.6]	1149 [27.2]	1011 [23.6]	
25-29	1599 [27.0]	1353 [25.8]	959 [22.7]	1006 [23.5]	
30-34	973 [16.5]	956 [18.2]	758 [17.9]	1003 [23.5]	
35+	586 [9.9]	577 [11.0]	563 [13.3]	632 [14.8]	
Total	5913 [100.0]	5248 [100.0]	4229 [100.0]	4274 [100.0]	

IQR, interquartile range.
[a]Missing approximately three-quarters of the information regarding the starting month of antenatal care visits.
[b]Chi-square tests comparing the four cohorts.

caesarean sections and income. More details about the use and interpretation of these indices are presented elsewhere.[23] All analyses were performed using the Stata 15.1 software.[24]

Results

Our analyses are based on women with information about the number of antenatal care visits and type of delivery. These amounted to 5983, 5292, 4106 and 4286 mothers from the 1982, 1993, 2004 and 2015 cohorts, respectively.

Table 1 shows that although the median number of antenatal care visits was similar in the four cohort studies, the proportion of women with eight or more visits increased considerably from around 40% in 1982 to over 60% in 2015. In 1982, 34.9% of women who started ANC in the first trimester of pregnancy had eight or more ANC visits, increasing to 47% in 1993 and 50.5% in

Table 2. Proportion of mothers who attended at least six antenatal visits during pregnancy, according to quintiles of family income and skin colour, for each of the four Pelotas Birth Cohorts [1982, 1993, 2004 and 2015]

Variable	Birth cohort year				*P*-value
	1982	1993	2004	2015	
	% [CI 95%]	% [CI 95%]	% [CI 95%]	% [CI 95%]	
Total	3999 [66.8]	3916 [74.0]	3301 [80.4]	3588 [83.7]	
Quintiles of family income					
Q1 [poorest]	44.9 [42.; 47.7]	58.9 [55.9;- 61.9]	66.8 [63.6; 70.0]	70.0 [66.9; 73.1]	<0.001
Q2	59.1 [56.3; 61.8]	68.1 [65.5; 70.8]	71.0 [67.9; 74.1]	78.7 [76.0; 81.5]	<0.001
Q3	68.0 [65.4; 70.7]	75.9 [73.1; 78.7]	80.9 [78.1; 83.6]	85.6 [83.2; 88.0]	<0.001
Q4	77.6 [75.3; 80.0]	79.1 [76.6; 81.6]	89.0 [86.8; 90.6]	88.4 [86.3; 91.1]	<0.001
Q5 [richest]	85.3 [83.3; 87.3]	90.3 [88.4; 92.1]	94.8 [93.3; 96.3]	95.7 [94.3; 97.1]	<0.001
Skin colour					
White	69.9 [68.6; 71.2]	78.1 [76.9; 79.4]	83.8 [82.4; 85.1]	86.9 [85.7; 88.1]	<0.001
Brown	–[a]	63.7 [57.5; 69.9]	78.3 [73.5; 83.1]	78.1 [74.7; 81.5]	<0.001
Black	52.8 [49.8; 55.8]	59.1 [56.0; 62.2]	68.8 [65.6; 72.0]	73.9 [70.5; 77.3]	<0.001

CI – Confidence interval.
[a]Absent category in the 1982 birth cohort. In 1982, mother's skin colour was recorded as White or Other.

2004. As mentioned, the information for 2015 was not comparable and is not presented. A more detailed description of the sociodemographic characteristics of the cohort participants is presented in the methodological paper that is part of this issue.[21] The caesarean section rate increased by almost 40% age points from 1982 to 2015, being more prevalent than vaginal deliveries in 2015. In 1982 and 1993, around 30% of women gave birth by caesarean section. In 2004 almost 50% of deliveries were by caesarean section, and 65% of women from the 2015 cohort gave birth by caesarean section [Table 1].

Table 2 shows that the proportion of mothers with at least six ANC visits increased in all income quintiles. However, the proportion of mothers who had at least six visits was always higher and almost universal in women in the richest group in 2004 and 2015. The prevalence of at least six antenatal care visits was also higher in White mothers, compared with Brown and Black mothers, in all four cohorts. The median numbers of visits by income and skin colour are presented in Supplementary Table 1, available as Supplementary data at *IJE* online, and show patterns similar to those observed in Table 2.

Results for antenatal care adequacy according to the Kessner classification are presented in Supplementary Table 2, available as Supplementary data at *IJE* online. Given that this is a more stringent classification than the previous indicator on six or more visits, it is not surprising that coverage levels are lower for all income and skin colour groups, and that inequalities become even more evident. A similar situation was observed when we assessed the proportion of mothers who had started ANC visits in the first trimester of pregnancy and attended at least six ANC visits. The proportions of women increased with time, being higher among high-income and White mothers [Table 3].

The prevalence of caesarean sections increased from 1982 to 2015 for all income quintiles [Table 4], but remained highest in the richest quintile, among whom nearly 90% gave birth by caesarean section in 2015. Caesarean sections were more common than vaginal deliveries in the four cohort studies when delivery was paid by private health insurance or out of pocket. In 2004 and 2015, caesarean sections were almost universal in the private sector [84.5% and 93.9%, respectively]. There was also a marked increase in caesarean sections in the public sector from 1982 to 2015, from 24% to over 50% of all deliveries [Figure 1].

Absolute income-related inequality decreased over time for more than six ANC visits. The slope index dropped 17% age points from 1982 to 2015, but most of the reduction was concentrated between 1982 and 1993. From 2004 to 2015, the reduction was only 6% age points. For more than six ANC visits starting in the first trimester, the pattern was less clear. There was a 17-percentage point reduction in absolute inequality from 1982 to 1993, but it increased in 2004 by 7% age points. Relative inequality followed approximately the same pattern [Table 5]. Sizeable inequalities persist in 2015.

With a steep overall increase in caesarean sections, especially for the richest mothers, it is not surprising that we see an increase in absolute inequality along time. The slope index increased from around 29% to nearly 41% age points from 1982 to 2015. The increase in inequality was more marked in the last period. For relative inequality the

Table 3. Proportion of mothers who attended at least six antenatal visits during pregnancy starting in the first trimester, according to quintiles of family income and skin colour, for each of the four Pelotas Birth Cohorts [1982, 1993, 2004 and 2015]

Variable	Birth cohort year				*P*-value
	1982[a]	1993	2004	2015	
	% [CI 95%]	% [CI 95%]	% [CI 95%]	% [CI 95%]	
Total	1028 [48.2]	3311 [63.7]	2684 [65.5]	–	<0.001
Quintiles of family income					
Q1 [poorest]	32.3 [27.6; 37.4]	51.0 [47.8; 54.3]	53.5 [49.7; 56.7]	–	<0.001
Q2	45.8 [40.6; 51.2]	60.6 [57.7; 63.5]	52.1 [48.7; 55.6]	–	<0.001
Q3	54.0 [48.7; 59.2]	67.0 [63.8; 70.1]	65.8 [62.3; 69.0]	–	<0.001
Q4	62.9 [58.0; 67.6]	71.8 [68.9; 74.5]	77.9 [74.9; 80.6]	–	<0.001
Q5 [richest]	81.7 [77.6; 85.2]	84.7 [82.3; 86.8]	87.8 [85.3; 89.8]	–	<0.001
Skin colour					
White	59.2 [56.7; 61.7]	70.8 [69.3; 72.2]	71.7 [70.0; 73.3]	–	<0.001
Brown	–[b]	57.1 [50.3; 63.7]	63.9 [58.1; 69.4]	–	<0.001
Black	41.8 [36.4; 47.5]	52.6 [49.3; 56.0]	53.0 [49.4; 56.5]	–	< 0.001

CI, confidence interval.
[a]The information regarding the starting month of antenatal care visits is missing for approximately three-quarters of the mothers.
[b]Absent category in the 1982 birth cohort. In 1982, mother's skin colour was recorded as White or Other.

Table 4. Proportion of births by caesarean section according to quintiles of family income, for the four Pelotas Birth Cohorts [1982, 1993, 2004 and 2015]

Variable	Birth cohort year				*P*-value
	1982	1993	2004	2015	
	n [%]	*n* [%]	*n* [%]	*n* [%]	
Total	1659 [27.6]	1620 [30.5]	1937 [45.2]	2808 [64.9]	<0.001
	% [CI 95%]	% [CI 95%]	% [CI 95%]	% [CI 95%]	
Quintiles of family income					
Q1 [poorest]	16.8 [14.7; 18.9]	23.6 [21.0; 26.1]	38.3 [35.1; 41.5]	50.5 [47.1; 53.8]	<0.001
Q2	24.4 [22.0; 26.8]	23.1 [20.7; 25.5]	35.1 [31.9; 38.3]	55.4 [52.1; 58.7]	<0.001
Q3	22.0 [19.6; 24.3]	27.4 [24.5; 30.3]	42.2 [38.9; 45.6]	63.7 [60.5; 66.9]	<0.001
Q4	31.8 [29.1; 34.4]	32.9 [30.0; 35.8]	46.6 [43.3; 49.9]	68.7 [65.6; 71.8]	<0.001
Q5 [richest]	43.4 [40.5; 46.2]	47.0 [44.0; 50.1]	64.5 [61.2; 67.7]	86.2 [83.9; 88.5]	<0.001
Skin colour					
White	28.9 [27.7; 30.2]	32.1 [30.7; 33.6]	46.3 [44.6; 48.1]	68.0 [66.4; 69.6]	<0.001
Brown	–[a]	27.4 [22.1; 33.5]	45.2 [39.6; 50.9]	57.6 [53.5; 61.7]	<0.001
Black	21.6 [19.3; 24.2]	24.8 [22.2; 27.6]	41.1 [37.9; 44.4]	56.3 [52.5; 60.1]	<0.001

CI, confidence interval.
[a]Absent category in the 1982 birth cohort. In 1982, mother's skin colour was recorded as White or Other.

trend was the opposite, with a modest reduction in the concentration index from 17 to 10.

Discussion

Our study is based on four population-based birth cohorts from Pelotas [Brazil]. Despite not being nationally representative by design, these studies reflect the national trends in the country, given that the Brazilian public health system has national coverage and is largely funded and regulated by the federal government. Further, despite being geographically distant, Pelotas is a medium-sized city by Brazilian standards, with a per capita GDP close to the municipalities average; Pelotas has a per capita GDP of R$21 553, compared with a national average of R$19 504 [2015 estimates, source: IBGE URL: https://goo.gl/f6kgN2]. We explored antenatal care and caesarean sections, two important aspects of maternal health. ANC presented remarkable improvements on all income quintiles from 1982 to 2015. Income inequalities, in both absolute and relative terms, were markedly reduced. At the same time, the proportion of deliveries by caesarean section increased so markedly that in 2015 caesarean sections were more common than vaginal deliveries, in both private and public sectors.

The high prevalence of caesarean sections is not restricted to Pelotas, but was recorded in Brazil as a whole. A recent global analysis, comparing 150 countries, showed that in 2014 Brazil was second only to the Dominican Republic, with 55.6% and 56.4% caesarean deliveries, respectively.[25] An assessment of caesarean sections in Brazil concluded that they were more common among women at low risk of maternal or fetal death, suggesting that the option for this type of delivery was mostly elective.[26] A study performed in the Brazilian state of Rio de Janeiro not only supports this hypothesis but places a good deal of responsibility on the health services, since they showed that 70% of the women did not report a preference for caesarean section at the start of pregnancy, but in the end 90% underwent caesarean section.[27] A national study found a similar result for primiparous women in the private sector, but a less extreme change in the public sector. Here, 72% of the women declared a preference for a vaginal delivery, and in the end 43% delivered vaginally. The reasons behind the preference for deliveries by caesarean section are many, involving women's fear of pain,[27,28] financial benefits for the hospitals or doctors,[29] ability to schedule the delivery on a given day and the idea that caesarean sections are related to better quality care since they are preferred by rich women.[26] Women who declared a preference for a vaginal delivery mostly referred to a better recovery after a normal birth.[28] In our study, caesarean section rates were unacceptably high, mainly among the more affluent women or those who gave birth in private sector care. The World Health Organization [WHO] has recently re_asserted its position on the ideal proportion of caesarean sections, and showed that values above 10% are not associated with reduced mortality outcomes.[30]

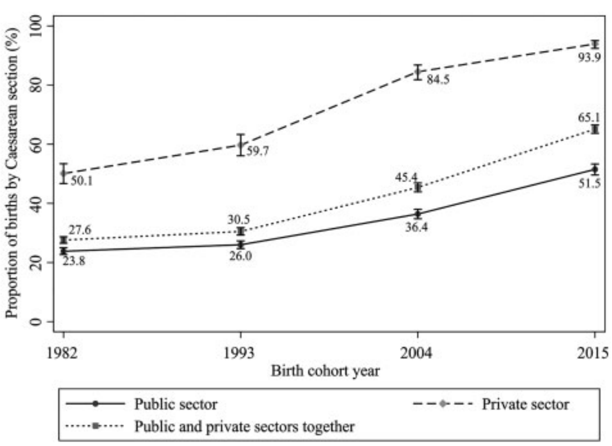

Figure 1. Proportion of births by Caesarean section, total and by public or private sector, for each Pelotas birth cohort (1982, 1993, 2004 and 2015). The 95% confidence intervals are indicated by the vertical lines for each data point.

Inequalities in caesarean section rates behaved in a way that may seem odd, with absolute inequality increasing and relative inequality decreasing. However, with a steep increase in overall rates this is not an uncommon pattern, given that ratios tend to decline when the coverage for all groups increase. What is clear is that the distance between the extremes of the wealth distribution increased in the period between 2004 and 2015, with an increase of 21% age points in caesarean section rates for the richest group, and an increase of 12%age points for the poorest group.

In contrast, the increase in antenatal care coverage from 1982 to 2015 is an important step towards achieving universal health coverage, as proposed by SDG number 3.[2] This increase occurred in all income quintiles. In 2015, even before the new World Health Organization guidelines recommended at least eight antenatal visits, 63% of the women had already achieved this goal.[31] ANC coverage in Brazil, regardless of the indicator used, is substantially higher and wealth-related inequalities are considerably less marked than in most other low- and middle-income countries.[32] Nevertheless, in spite the observed reduction in

Table 5. Income inequalities for attending at least six antenatal care visits, for attending at least six antenatal care visits starting in the first trimester of pregnancy and for caesarean section

Outcome	Birth cohort year			
	1982	1993	2004	2015
At least six antenatal visits				
Slope index of inequality [SII]	47.3 [43.9; 50.8]	36.0 [32.2; 39.8]	36.5 [32.6; 40.5]	30.3 [26.5; 34.1]
Concentration index [CIX]	11.5 [10.5; 12.6]	4.5 [3.6; 5.5]	5.3 [4.4; 6.1]	4.2 [3.5; 4.9]
At least six antenatal visits starting in the first trimester of pregnancy				
Slope index of inequality [SII]	55.0 [49.0; 60.9]	37.9 [33.8; 42.0]	45.0 [40.7; 49.3]	–
Concentration index [CIX]	10.0 [7.7; 12.4]	4.0 [2.9; 5.2]	6.1 [4.9; 7.4]	–
Caesarean section				
Slope index of inequality [SII]	29.3 [25.6; 33.1]	27.6 [23.3; 31.8]	30.5 [25.7; 35.3]	40.6 [36.3; 44.8]
Concentration index [CIX]	17.1 [14.7; 19.4]	13.6 [11.2; 16.0]	9.7 [7.8; 11.6]	10.3 [9.1; 11.6]

both absolute and relative inequalities, our results still reveal marked differences in ANC coverage across income and ethnic groups. In 2015, the slope index still showed a 30-percentage point difference between the extremes of income distribution, and there was a 13-percentage point difference between White and Black mothers for more than six ANC visits. The observed patterns of inequality are confirmed by our analyses using the Kessner index for antenatal care [Supplementary Table 2, available as Supplementary data at *IJE* online], which accounts for the fact that shorter durations of gestation tend to be associated with fewer visits.[22] Data from national surveys confirm the pattern of decreasing inequalities. These analyses show that whereas coverage with at least one ANC visit was almost universal in the whole country, there were important inequalities in coverage with four visits, and even greater disparities when six visits were considered.[33]

Our results suggest that ANC coverage is consistently lower in those groups of women that typically present higher risks of maternal and infant mortality.[3,4] To achieve the SDG goal of 'ensure healthy lives and promote well-being for all people at all ages', it is essential to achieve higher coverage in the most vulnerable groups. In Brazil, home ANC is already part of the Family Health Strategy targeted at vulnerable communities throughout the country, which may explain the decline in inequality.[34]

The Pelotas Birth Cohorts are rigorous studies that share location, methods and recruitment strategy, and thus enable us to draw a very precise picture of trend in antenatal and delivery care over more than 30 years. Nevertheless, some limitations must be noted. In 1982, information on the date of the first ANC visit was not collected for deliveries taking place from January to August. In this cohort, skin colour was coded as White or Other, instead of the three categories [White, Brown And Black] used in the later studies. The colour distribution for the four cohorts suggests that most women classified as Brown women ended up classified as White. Another important limitation was the lack of comparability between the 2015 and the earlier cohorts regarding the gestational age at the first ANC visit, which yielded lower estimates for the indicator of six or more visits starting in the first trimester, and also resulted in a larger percentage of missing information [around 12%]. In all cohorts, most of the information was based on the mother's report in the perinatal interview, and there is always the risk of recall bias, especially considering that the hours after delivery are a time when a recent mother is mostly focused on the newborn. Finally, the timing of the first antenatal visit is particularly challenging for some of the mothers.

Our results showed an increase in the number of antenatal care visits in all income quintiles and skin colour groups, as well as an increase in ANC indicators coverage. In spite of this, inequalities are still sizeable. Special attention should be given to poor and Black women in order to increase their access to ANC and reduce these inequalities. We also showed that the prevalence of caesarean section is unacceptably high, especially among the women who are richer or have deliveries in the private sector. Reversing the current trend requires radical changes in delivery care policies.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: the Wellcome Trust [UK], International Development Research Center [IDRC, Canada], World Health Organization [WHO, Geneva], Overseas Development Administration [ODA, UK], European Union, Brazilian National Support Program for Centers of Excellence [PRONEX, Brazil], Brazilian National Council for Scientific and Technological Development [CNPq, Brazil], Science and Technology Department [DECIT] of the Brazilian Ministry of Health [Brazil], Research Support Foundation of the State of Rio Grande do Sul [FAPERGS, Brazil], Brazilian Child's Pastorate [Brazil] and Brazilian Collective Health Association Health [ABRASCO, Brazil].

Pelotas Cohorts Study Group

Alicia Matijasevich,[1] Ana M B Menezes,[2] Andrea Dâmaso Bertoldi,[2] Helen Gonçalves,[2] Iná S Santos,[2] Joseph Murray,[2] Luciana Tovo-Rodrigues,[2] Maria Cecilia F Assunção,[2] Marlos Rodrigues Domingues[2] and Pedro R C Hallal.[2]

[1]University of São Paulo, Brazil and [2]Federal University of Pelotas, Brazil.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i89–i93
doi: 10.1093/ije/dyy214
Commentary

Commentary

Commentary: A tale of many cities in one: the Pelotas (Brazil) Birth Cohorts, 1982–2015

Fernando C Barros[1] and Cesar G Victora[2]*

[1]Catholic University of Pelotas and [2]Federal University of Pelotas, Pelotas, Brazil

*Corresponding author. E-mail: cvictora@gmail.com

The nine articles in this Supplement present the main results from over three decades of epidemiological research in the city of Pelotas in Southern Brazil. Our first perinatal study was inspired by the British Births study of 1970, to which we were exposed as young trainees in the UK. With the strong support of Prof. Patrick Vaughan from the London School of Hygiene and Tropical Medicine, who supervised our doctoral degrees, we obtained international funding from Canada (International Development Research Center) and the UK (Overseas Development Administration) to launch the 1982 Pelotas Birth Cohort study. Since then, a new cohort has been launched every 11 years. Over 20 000 subjects, in our city of 340 000 inhabitants, are being followed up from birth. These datasets allow not only analyses of life course epidemiology within a given cohort, but also panel type, secular trend analyses in which individuals of similar age in the four cohorts are compared.

In the Supplement, we have focused on analyses that are primarily descriptive of the health and nutrition conditions of women who gave birth, and of infants who were born, in the years 1982, 1993, 2004 and 2015. We have a special focus on socioeconomic and ethnic group inequalities, and on how these evolved over time. Our first analyses of the 1982 cohort documented the abysmal social and ethnic gaps in health, which paralleled the economic inequalities that have defined Brazilian society since early colonization and slavery. Indeed, our first book came out in 1988 with the title '*The Epidemiology of Inequality*', describing differences between rich and poor mothers and children belonging to the 1982 Birth Cohort.[1]

In the 33 years that elapsed between the first and the fourth cohorts, Brazil in general and Pelotas in particular experienced major changes in all aspects of life and society—socioeconomic development, culture, moral values, physical environment, technology, demography, nutrition, health care systems—all of which impacted directly on the lives of the Birth Cohort populations. Starting off as slightly more developed than Brazil as a whole, Pelotas became relatively poorer: the city was 9% above the national gross development product per capita in 1982, and is now 26% below.[2] The decline was largely due to the bankruptcy of the city's main economic activity in the 1980s—the canned fruit and food industries—due to the opening of the national market to cheap, subsidized foreign products in the 1990s. The social history of Pelotas is also affected by the fact that it is located in an area of large plantations and cattle farms with few landholders and many impoverished labourers, and by the forced immigration of African slaves in the 19th century to work on the salted meat (or jerky) industry.

The accompanying articles document major changes in several aspects of the health and nutrition of women and children. Table 1 summarizes the observed changes in six major sets of indicators: the profile of women giving birth; health care during pregnancy, delivery and infancy; maternal nutrition; newborn health; fetal and infant mortality and morbidity; and nutrition during infancy. In the table, we have used terminology such as 'increased', 'decreased' or 'stable', based on the trends, confidence intervals and *P*-values reported in the nine preceding articles. We also report on trends among 'rich' (top two income quintiles) and 'poor' (bottom two income quintiles)[2,11] women and children, and taking into account the evolution of the indicators of absolute (the slope index) and relative (the concentration index) inequalities. We focus on changes

Table 1. Classification of health indicators according to time trends in levels and inequalities. Pelotas, Brazil, 1982–2015

Group[a]	Health indicators (reference)	Trends	Inequality pattern (group with higher frequencies)		Changes in income-related inequalities over time	
		Values in 2015 compared with 1982	1982	2015	Absolute inequality	Relative inequality
	Sociodemographic					
A	Maternal schooling[2]	Increased	Rich	Rich	Reduced	Stable
	Environmental					
A	Household appliances[2]	Increased	Rich	No clear pattern	Reduced	Reduced
A	Access to treated water[2]	Increased	Rich	No clear pattern	Reduced	Reduced
	Maternal nutrition					
A	Maternal height[3]	Increased	Rich	Rich	Reduced	Reduced
A	Maternal underweight[3]	Decreased	Poor	Poor	Reduced	Reduced
D	Maternal overweight[3]	Increased	Middle class	Middle class	Stable	Stable
D	Weight gain in pregnancy[3]	Increased	Rich	No clear pattern	Reduced	Reduced
	Reproductive history					
B	Maternal age <20 years[2]	Decreased	Poor	Poor	Increased	Increased
C	Maternal age >35 years[4]	Increased	Rich	Rich	Increased	Increased
B	Parity >0[4]	Decreased	Poor	Poor	Increased	Increased
B	Short birth interval[4]	Decreased	Poor	Poor	Increased	Increased
	Newborn health and nutrition					
E	Low birthweight[5]	Stable	Poor	Poor	Reduced	Reduced
E	ICU stay after birth[6]	Increased	No clear pattern*	No clear pattern	Stable	Stable
C	Multiple births[4]	Increased	No clear pattern	Rich	Increased	Increased
	Pregnancy and delivery care					
A	Antenatal care >5 visits[7]	Increased	Rich	Rich	Reduced	Reduced
C	Caesarean sections[7]	Increased	Rich	Rich	Increased	Reduced
	Mortality and hospital morbidity					
A	Fetal mortality[8]	Decreased	Poor	Poor	Reduced	Stable
E	Neonatal mortality[8]	Decreased	Poor	Poor	Stable	Stable
A	Infant mortality[8]	Decreased	Poor	Poor	Reduced	Stable
A	Hospital admissions[6]	Decreased	Poor	Poor	Reduced	Reduced
	Breastfeeding					
B	Breastfeeding at 12 months[9]	Increased	Poor	No clear pattern	Reduced	Reduced
B	Exclusive BF at 3 months[9]	Increased	Rich*	Rich	Increased	Reduced
	Child nutrition (12 months)					
A	Stunting[10]	Decreased	Poor	Poor	Reduced	Reduced
A	Wasting[10]	Stable	Poor	No clear pattern	Reduced	Reduced
D	Overweight[10]	Increased	Rich	Poor	Reduced	Reduced

ICU, intensive care unit; BF, breastfeeding.

[a]Group A: indicators that improved for the whole population and also showed faster progress among the poor, thus leading to reduced inequalities, at least in absolute terms. Group B: indicators with overall improvement, but for which social inequalities increased due to slower progress among the poor. Group C: indicators whose overall prevalence increased over time, mostly due to rapid increases among the rich. Group D: indicators related to the nutrition transition, which showed major increases over time. Group E: indicators that did not fit into any of previous categories.

between the two extreme years, 1982 and 2015; most changes took place gradually over time, and those for which there was evidence on non-linearity are described in the individual articles in the Supplement.

The profiles of women giving birth changed markedly. The total number of births fell from 6011 in 1982 to 4329 in 2015, in spite of a near 50% increase in the city's population; the birth rate fell from 23 to 13 births per thousand in this period. Fertility reduction was most marked among White mothers, whereas the number of births to women with Black or Brown skin colour remained stable in the four cohorts.[2] On the other hand, the proportion of children born to poor families and to uneducated mothers decreased substantially, as the average schooling went up from 6.5 to 9.8 years.[2] The proportion of adolescent mothers remained stable, but there was a marked increase in mothers aged 35 years or older.[4] Half of all mothers are now primiparae, compared with 39% in 1982, and birth intervals became substantially longer.[4] These findings show a marked demographic transition coupled with improved education and income, in spite of Pelotas having lost ground compared with more rapid changes in the rest of the country.

Health care also changed markedly. Whereas in 1982, 6% of the women had no health care coverage and gave birth in charity hospitals, in 1988 a national health service was created by the national constitution approved at the end of a long period of military dictatorship. Antenatal care improved in quantitative terms, with an average of over eight consultations per woman,[7] but at the same time a massive epidemic of caesarean sections took place. In an article reporting on the caesarean section rates in 1982,[12] we used the term 'epidemic' to describe the 28% rate; little did we know that 33 years later the rate would increase to 65%. Caesarean sections are concentrated among women with high socioeconomic position, reaching 85% of all births to these women in 2015.[7] Scheduled caesarean sections, when the fetus is estimated to have reached 38 weeks of gestation, are the rule in this group.

The nutritional status of the mothers changed markedly. Low stature and underweight at the beginning of pregnancy were reduced, but 47% of the women were overweight or obese at conception, compared with 22% in 1982. There was also a sharp increase in women who gained more weight than recommended during pregnancy.[3]

The incredibly high caesarean section rate is likely to have contributed to the stabilization of low birthweight prevalence at around 10% in the last three cohorts. Birthweights would be expected to increase in light of better maternal nutrition, improved socioeconomic status and increased access to health care, but their stability signals that other factors evolved in an opposite direction. Analyses of time trends in preterm births are affected by changes in the way gestational age was assessed, but nevertheless there is evidence of a major increase in prevalence, which is in agreement with other Brazilian studies.[5]

Fetal, neonatal and infant mortality rates decreased markedly. Deaths due to diarrhoea and other infections showed the fastest decline.[8] Hospital admissions also declined, again mostly due to reductions in infectious diseases. In contrast, admission to neonatal intensive care units increased, following the increase in availability of these beds and in the number of preterm births.[6]

Last, the durations of exclusive and any breastfeeding increased sharply.[9] The prevalence of stunting at 12 months of age fell, whereas the prevalence of overweight more than doubled.[10]

We have attempted to summarize the evolution of maternal and child indicators over time, by taking into account the levels, confidence intervals and *P*-values for overall trends and inequality indices reported in this Supplement's nine preceding articles. We were able to identify five groups of indicators (Table 1).

Group A includes indicators that improved for the whole population and also showed faster progress among the poor, thus leading to reduced inequalities, at least in absolute terms. These include maternal schooling, water supply and availability of household appliances, maternal height and underweight, antenatal care, fetal and infant mortality, hospital admissions and infant undernutrition.

Group B also includes indicators with overall improvement, but for which social inequalities increased due to slower progress among the poor. This was the case for three indicators related to reproductive history: parity, short birth intervals and teenage pregnancies. This group also includes the two breastfeeding indicators. Exclusive breastfeeding at 3 months started near zero and increased more rapidly among the rich than among the poor; and inequalities no longer exist in continued breastfeeding at 12 months, which was more common among the poor in 1982. These trends likely reflecting faster uptake by the rich of promotion efforts.[13]

Group C includes three indicators associated with higher risk for women and children. These are unnecessary caesarean sections, births to women aged 35 years or older and multiple births. Their overall prevalence increased over time, mostly due to rapid increases among the rich.

Group D includes indicators related to the nutrition transition, which showed major increases over time. Prepregnancy overweight and obesity were most common among women in the intermediate income groups throughout the 33-year period. Excessive gain during pregnancy and overweight prevalence at 12 months both increased, particularly among the poor, so that the initial finding of higher prevalence among the rich was obliterated or even reversed over time, as was the case for child overweight.

Last, three indicators did not fit into any of these categories. Low birthweight remained stable over time, but disparities were reduced because of increased prevalence among the rich. Neonatal mortality rates fell over time for all groups, but inequalities remained stable with higher rates among the poor. Neonatal intensive care admissions increased over time, but there are no clear disparities according to income, although the higher fetal and neonatal mortality rates among the poor would suggest that there should be fewer admissions among the better-off.

A comprehensive review of maternal and child health trends in Brazil, covering the period from the 1980s to 2010,[14] showed that the changes observed in the four Pelotas cohorts are in line with the what was observed in analyses of secondary national data. The review suggested that the observed improvements were likely due: to positive changes in the social determinants of health, with consequent reduction in extreme poverty and improvements in women's education; to vertical programmes in the 1980s and 1990s against infectious diseases (diarrhoea and pneumonia control programmes, immunization programmes and breastfeeding promotion); to the creation of the national health service in 1988, with universal access to health care and deployment of primary health care teams in rural and slum areas, contributing to reduced fertility and child mortality; and finally to progress in other sectors such as water and sanitation, education, transportation, communications and—in particular—cash transfer programmes.[14] The review also noted the marked increase in preterm deliveries, caesarean sections and overweight or obesity among women and children.

Regarding ethnic inequalities, we applied the official, widely-used Brazilian classification based on self-reported skin colour, with three main groups: White, Brown (usually mixed European and African ancestry) and Black.[2,15] The proportion of births by Brown and Black mothers increased from 18% to 28% during the study period, which is likely due to differential fertility as well as to affirmative actions which mean that more women are self-reporting to be Black or Brown.[15] Health differentials according to skin colour closely followed those reported above, using stratification by income groups. This was expected, given the longlasting heritage from slavery with the consequent association between poverty and ethnicity.[2] Nevertheless, some results merit discussion. The prevalence of adolescent pregnancy was higher among Black and Brown mothers, remaining stable over time at around 20%, well above that for White mothers. In addition, though the overall rate of late fetal mortality fell by half in the city, it remained stable at around 20 deaths per 1000 births among Black mothers.[8] The only health indicator for which Black mothers and children had an advantage over Whites was breastfeeding at 12 months of age.[9]

The present series allows a more granular understanding of these trends, due to our ability to report on a large number of primarily collected indicators that are not available from secondary data, and especially the ability to disaggregate overall trends by socioeconomic position and ethnicity. We show that for most indicators, overall progress was accompanied by—and in fact due to—a reduction in inequalities, a win-win combination that countries should strive for. However, there were several exceptions, including indicators for which progress was accompanied by an exacerbation of inequalities, and others for which a reduction in inequalities was due to worsening situation of the poor (as for overweight) or of the rich (as for low birthweight).

By carrying out four cohort studies in the same city over more than 30 years, we have learned several lessons for other similar studies. These include: the importance of having population-based samples at the start, reflecting the full spectrum of socioeconomic and environmental conditions; the importance of using strategies to minimize losses to follow-up through involvement of the cohort members, feedback on main findings and considerate handling by the study team; and the need to adapt the topics under study to the epidemiological and nutritional transitions faced by Brazilian society.

The profound social inequalities expressed in our health indicators show that instead of being a single, homogeneous urban area, Pelotas is indeed a city made up of many cities, often with several-fold differences in health indicators according to the socioeconomic position of the women and their children, with dynamic changes over time. We are deeply indebted to the over 20 000 subjects and to their families who inhabit these many cities; without their continued support we could never have achieved the low rates of non-response that characterize our cohorts.[2]

Our analyses confirm the importance of looking beyond aggregated data, in order to understand the levels and trends in health inequalities, and propose ways in which these can be overcome. We can only hope that when the 2026 cohort takes place—as it surely will—most if not all of the challenges reported here will have been tackled.

Conflict of interest: None declared.

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IJEA

International Journal of Epidemiology, 2019, i4–i15
doi: 10.1093/ije/dyy170
Supplement Article

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Trends and inequalities in maternal and child health in a Brazilian city: methodology and sociodemographic description of four population-based birth cohort studies, 1982–2015

Andréa Dâmaso Bertoldi,[1]* Fernando C Barros,[2] Pedro R C Hallal,[1] Gregore I Mielke,[1] Paula D Oliveira,[1] Maria Fatima S Maia,[3] Bernardo L Horta,[1] Helen Gonçalves,[1] Aluísio J D Barros,[1] Luciana Tovo-Rodrigues,[1] Joseph Murray,[1] Cesar G Victora[1] and the Pelotas Cohorts Study Group**

[1]Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil, [2]Postgraduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil and [3]Institute of Human Sciences and Information, Federal University of Rio Grande, Rio Grande, Brazil

*Corresponding author. Postgraduate Program in Epidemiology, Federal University of Pelotas, Marechal Deodoro, 1160, Pelotas, RS 96020-220, Brazil. E-mail: andreadamaso.epi@gmail.com
**Members listed at end of article.

Editorial decision 6 July 2018; Accepted 8 October 2018

Abstract

Background: Few low-middle-income countries have data from comparable birth cohort studies spanning over time. We report on the methods used by the Pelotas cohorts (1982, 1993, 2004 and 2015) and describe time trends in sociodemographic characteristics of the participant families.

Methods: During the four study years, all maternity hospitals in the city were visited daily, and all urban women giving birth were enrolled. Data on socioeconomic and demographic characteristics were collected using standardized questionnaires, including data on maternal and paternal skin colour, age and schooling, maternal marital status, family income and household characteristics. The analyses included comparisons of time trends and of socioeconomic and ethnic group inequalities.

Results: Despite a near 50% increase in the city's population between 1982 and 2015, the total number of births declined from 6011 to 4387. The proportion of mothers aged $\geq$35 years increased from 9.9% to 14.8%, and average maternal schooling from 6.5 [standard deviation (SD) 4.2] to 10.1 (SD 4.0) years. Treated water was available in 95.3% of households in 1982 and 99.3% in 2015. Three-quarters of the families had a refrigerator in 1982, compared with 98.3% in 2015. Absolute income-related inequalities in maternal schooling, household crowding, household appliances and access to treated water were markedly reduced between 1982 and 2015. Maternal skin colour was associated with inequalities in age at childbearing and schooling, as well as with household characteristics.

Conclusions: During the 33-year period, there were positive changes in social and environmental determinants of health, including income, education, fertility and characteristics of the home environment. Socioeconomic inequality was also reduced.

Key words: Maternal health, child health, socioeconomic factors, cohort studies, health surveys

Key Messages

- From 1982 to 2015, fertility in Pelotas declined by 44% and, despite a near 50% increase in the city's population, the number of births declined from 6011 to 4387.
- The proportion of adolescent mothers remained stable at around 15-19%, but the proportion of mothers aged ≥35 years increased from 10 % to 15%.
- There were important improvements in social and environmental determinants of health including family income, parental education and access to safe water.
- Absolute income-related inequalities in most social and environmental conditions improved markedly.
- Black or brown maternal skin colour was associated with inequalities in age at childbearing and schooling, as well as with household characteristics, compared with white women.

Introduction

Cohort studies have been a vital tool in the development of epidemiology and identification of determinants of health and illness, having served as the basis for many advances in population health by strengthening the evidence base for public health decisions. In particular, there is growing interest in the understanding of how exposures in early life may have long-term consequences for health throughout the life-course,[1,2] and birth cohort studies are particularly well suited to test a large number of health hypotheses, especially those involving long latency periods.

There is considerable interest among governments, universities and funding organizations in prospective cohort studies, most of which have taken place in high-income countries (HICs).[3] Cohort studies in low- and middle-income countries (LMICs) are less common but can make important contributions to this growing literature in several ways. First, LMIC cohorts can investigate risk factors (e.g. intrauterine growth restriction) or outcomes (e.g. infectious diseases) that are rare in HICs. Second, some health exposures differ between settings; for example, physical activity in LMICs is largely related to manual labour and commuting to work, whereas in HICs it is due to leisure-time exercise. Third, remarkably wide socioeconomic differentials are often observed in LMIC cohorts, compared with narrower social gaps in HICs, and this allows a deeper understanding of social determinants of health. And last, confounding factors that are observed in HICs—for example, longer duration of breastfeeding among rich and educated women—may show opposite patterns in LMICs, where breastfeeding is often more prevalent among the poor. Causal inference may be strengthened if results from both types of settings are consistent.[4] For example, a comparison of the Pelotas 1993 cohort with the British Avon Longitudinal Study of Parents and Children (ALSPAC) showed that associations between breastfeeding and intelligence quotient were similar in spite of different confounding patterns,[5] indicating a potential cause-effect relationship.

Brazil is the fifth most populous country in the world, with nearly 210 million inhabitants. The country has experienced rapid demographic, economic, nutritional and epidemiological transitions in the recent past, with a huge impact on maternal and child health,[6] In spite of progress, social inequalities in health have persisted, which is not unexpected given the strong concentration of wealth in a small segment of the Brazilian population,[7] Recent instability in the economic and political arenas may revert improvements in health that were due to a major reduction in poverty that have occurred since the 1990s.[8] In addition, the current crisis has had a marked negative impact on health spending as well as on scientific and technological development.[9]

Few if any LMICs have data from comparable, population-based birth cohort studies spanning back over three decades. We report on the four studies carried out in the city of Pelotas in Southern Brazil in 1982, 1993, 2004 and 2015, in which about 20 000 children, adolescents and adults are being followed up since they were born. Although the early Pelotas cohorts focused mostly on child mortality and the consequences of early under-nutrition (in both the short and long term), our interest evolved over time to studying psychomotor development, overweight/obesity and body composition, physical activity, mental health and violence. The evolution of the topics under study followed the health and nutrition transition observed in Brazilian society.[6] Technical advances also led us to collect information on biomarkers and to study the genomes of cohort members, which was not possible when the first two cohorts were launched.[10,11]

The four birth cohorts allow comparisons of health, nutrition and human capital indicators over three decades as well as the study of trajectories over time within each cohort. In this article, the first of a supplement, we report the methods used in the four cohorts for documenting time trends in maternal, newborn and infant health over 33 years, as well as for studying how socioeconomic, ethnic and sex inequalities evolved through time. We also describe the socioeconomic and environmental characteristics of the families included in the four cohorts. The remaining articles in the supplement describe characteristics of the mothers (reproductive history, nutritional status, health care during pregnancy and delivery) and of their infants (birthweight and gestational age, mortality, hospital morbidity, infant feeding and nutritional status).

Methods

Pelotas is a medium sized city in the state of Rio Grande do Sul, located in the south of Brazil (latitude: 31°46'19", longitude: 2°20'19"), near the Uruguayan border, occupying an area of 1610 km^2. According to the Brazilian Institute of Geography and Statistics, the municipal population reached 342 873 inhabitants in 2015, of whom 93.3% were urban residents. The main economic activities in Pelotas are agriculture (especially rice production), commerce and education.

From 1 January to 31 December in 1982, 1993, 2004 and 2015, all maternity hospitals in the city were visited daily, and all urban women giving birth were invited to join the study. The city boundaries have changed through time, and an area that was included in the urban perimeter in 1982 was later emancipated as a new municipality (Jardim America). To ensure comparability with the 1982 cohort, women from this neighbourhood were retained in all cohorts.

Primary data collection was conducted using standardized questionnaires to obtain information on socioeconomic, environmental, demographic, nutritional, behavioural and other health-related characteristics. In the 2015 study, we attempted to recruit mothers during antenatal care, to collect prospective information on pregnancy-related variables; 73.8% of the mothers who subsequently delivered children included in the cohort were recruited during antenatal care. All questionnaires are available at [http://www.epidemio-ufpel.org.br/site/content/studies/]. Detailed methodological information on each cohort is available elsewhere.[12–15]

After the perinatal study in hospitals, children were visited at home at different ages. In the 1982 cohort, due to limited funding, the first follow-up visit was carried out in early 1982 and was aimed at the 1916 children born from January to April 1982. Using information on home addresses collected in the perinatal interview, it was possible to locate four-fifths of the intended sample at the mean age of 11.3 months. In face of the low follow-up rate, a new strategy was used in the 2-year follow-up visit during 1984, when a census of all households in the city was carried out and resulted in locating seven out of every eight children born in 1982. For children who had not been traced in 1983, information on the first year of life was obtained retrospectively in 1984; for consistency with the other cohorts, this will be referred to as the 12-month visit. In the 1993 study a subsample of 1460 children, including all low-birthweight children (less than 2500 g) plus a random 20% of the remaining children, were visited at home when infants were aged 1, 3, 6 and 12 months. All children from the 2004 and 2015 were visited at home at the ages of 3 and 12 months. The cohorts continue to be followed up regularly up to the present time, but the analyses in this supplement refer to the first year of life.

Data collection was carried out by trained research team members. Participants were interviewed using standardized, pre-coded questionnaires. The size and complexity of the questionnaires increased substantially between cohorts. In the 1982 perinatal study, 80 questions were printed on the two sides of an A4 sheet. In 1993, the questionnaire comprised 16 pages and 212 questions; and in 2004, the number of pages increased to 25 with 273 questions (some of which were formatted as boxes that included large amounts of information). In 2015, tue questionnaire had 34 pages including 326 questions, and mobile tablets were used instead of paper. In addition to the questionnaire, all babies were weighed and measured. Further details regarding anthropometry and gestational age ascertainment are provided in other articles in this supplement.[16,17]

To standardize data collection, all team members were trained before each round of fieldwork. The training included general orientations on each question and pre-coded options, and instructions on how to approach the mother and the family in a polite manner. During the follow-up visits, quality control measures included regular calibration of scales and repetition by a supervisor of a subset of interview questions for 5% of the whole sample, including key variables such as age, smoking, education etc. During the fieldwork, interviews were also daily supervised by PhD students.

The analyses reported in the present supplement refer to pregnancies, deliveries and health in the first year of life. Socioeconomic and demographic characteristics were collected during the perinatal interview for the four cohorts: child sex (male, female), maternal and paternal skin colour (white, brown, black), maternal and paternal age in full years, marital status (single or living with partner), maternal and paternal schooling in completed years, family income (expressed in local currency and converted into minimum wages at the time of the perinatal interview), family income in quintiles (with Q1 being the poorest and Q5 the richest) and number of household members. A 'minimum wage' is a measure of the legal minimum monthly salary for formal employees in the state.

All analyses relied on data collected from birth to age 12 months, with some exceptions. Treated water supply at home (no, yes) was collected at the 24-month visit in the 1982 cohort, the 6-month follow-up of the 1993 study and during the 3-month follow-up of the 2004 cohort. Presence of a television and refrigerator at home (no, yes) was collected at 24 months for the 1982 cohort and at 6 months for the 1993 study. Paternal schooling was collected at the 12-month visit of the 1982 cohort. The number of household members and of bedrooms were collected when children were 3 months old in the 2004 and 2015 cohorts, but comparable information was not available for the earlier cohorts.

The official Brazilian classification of ethnicity is based on skin colour and includes three frequent categories (white, black or brown) in addition to the less frequent indigenous and yellow (Asian origin) groups. Due to very small number of observations in the Pelotas population, the last two categories were excluded from our analyses of skin colour. In 1982, the interviewer observed the colour of the mother and classified it as white, black or other (either indigenous or yellow); women with brown skin were classified as black. Observation was also used in 1993, but the questionnaire included an additional option for brown skin colour. In 2004 and 2015, the mother self-reported her skin colour according to the five categories, which is currently the standard, widely accepted approach for assessing ethnicity in Brazilian society.[18]

Chi-square statistics were used to test for linear trends over the study period. Inequalities in maternal and household characteristics within each cohort were also analysed using chi-square tests, including tests for trend when appropriate. To evaluate the magnitude of inequalities in maternal and household characteristics, the slope index of inequality and the concentration index were calculated.[19] The slope index is a measure of absolute inequality, being derived through a logistic regression model. It corresponds to the difference in percentage points between the fitted values of the health indicator for the top and the bottom of the wealth distribution. The concentration index reflects relative inequality and is based on a concept similar to the Gini index for income concentration. It expresses how far from total equality a given distribution is.[20] Both indices are expressed on a scale from -100 to +100, with zero representing equal distribution of the attribute across the wealth scale. All analyses were conducted with Stata software version 15.0.[21]

Ethical approval for studies was not required in Brazil until 1996. In 1982 and 1993, verbal consent was obtained from the mothers before the interview. The 2004 and 2015 studies were approved by the Ethics Committee of the Federal University of Pelotas, and written consent was obtained from the mothers. Further details on the methods of each cohort are available in previous publications.[10,11,13–15,22–28]

Results

The total numbers of births in 1982, 1993, 2004 and 2015 were 6011, 5304, 4287 and 4329, respectively. The corresponding numbers of live births were 5914, 5249, 4231 and 4275 (Figure 1), and those of singleton live births 5816, 5168, 4147, 4164, respectively. Refusal rates at the perinatal interview, when all urban women giving birth were invited, were 1.3% or less. Response rates at the 12-month interview were 79% in 1982 and above 93% for the 1993, 2004 and 2015 cohorts. In the 1982 cohort, a census of all households in the city increased the follow-up rate to 87.2% at the age of 2 years, when retrospective information on the first year of life was obtained. Figure 1 describes the timelines of the first year of each birth cohort, with response rates.

Table 1 shows characteristics of Pelotas over the time span of the cohort studies. The city population increased from nearly 250 000 to around 340 000 between 1982 and 2015. In 1982 almost a fifth of population was rural; this proportion decreased to 6.7% in 2015. The ratio between the gross domestic product (GDP) per capita in Pelotas and Brazil is also shown in Table 1. In 1982 Pelotas had a slight higher GDP per capita than Brazil, with a ratio of 1.09, but this ratio decreased to 0.74 by 2015, showing a relative impoverishment of the city. The number of hospitals, and

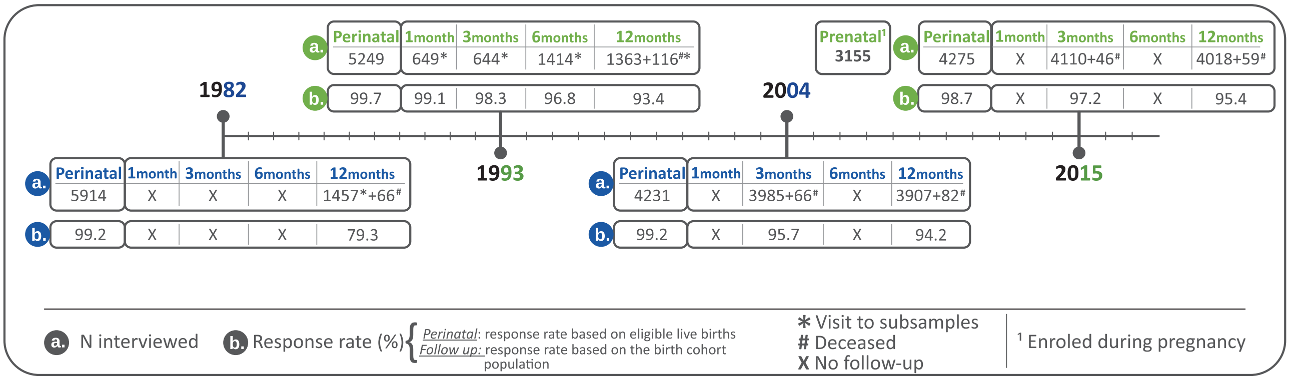

Figure 1. Numbers of live births and of children followed up during the first year of life in the Pelotas birth cohorts, showing response rates.

Table 1. Characteristics of Pelotas-RS, Brazil, over the cohort studies (1982–2015)

Characteristics	1982	1993[l]	2004	2015
Total population (thousands)[a]	250	300	335	343
% living in the urban area[a]	81.0	91.6	93.2	93.3
Municipal Human Development Index[b]	–	0.558[c]	0.660[d]	0.739[e]
Crude birth rate (births/1000 population)[f]	23.1[g]	19.3[h]	13.3	12.9
Gross Domestic Product per capita (US$)[i]	3989	–	2511	5953
Ratio Pelotas/Brazil: Gross Domestic Product[i]	1.09	–	0.61	0.74[j]
Gini index for income distribution[b]	–	0.59[a]	0.60[b]	0.56[c]
Brazilian monthly minimum wage (US$)[i]	77.4	31.4	88.9	236.9
Number of maternity hospitals	3	5	5	5
Number of hospital beds	1577	1431	1321	1169
Beds in paediatric intensive care units[k]	0	16	19	29
Primary health care units	37	59	59	54

[a]Estimates were derived through interpolation of the results of the 1980, 1991, 2000 and 2010 national censuses, and projections for 2015. Source: Brazilian Institute of Geography and Statistics (IBGE) [https://ww2.ibge.gov.br/home/estatistica/populacao/estimativa2015/estimativa_dou.shtm].
[b]Atlas of Human Development in Brazil [http://www.atlasbrasil.org.br/2013/ranking].
[c]Official data available for 1991, Atlas of Human Development in Brazil [http://www.atlasbrasil.org.br/2013/ranking].
[d]Official data available for 2000—Atlas of Human Development in Brazil—http://www.atlasbrasil.org.br/2013/ranking.
[e]Official data available for 2010, Atlas of Human Development in Brazil [http://www.atlasbrasil.org.br/2013/ranking].
[f]Estimate based on Brazilian Institute of Geography and Statistics and Live Birth Information System (SINASC) [http://tabnet.datasus.gov.br/cgi/tabcgi.exe?ibge/cnv/pibmunbrs.def].
[g]Non-official data. Estimate based on number of live births from 1982 Cohort.
[h]Official data available for 1994. Estimate based on SINASC.
[i]Fundação de Economia e Estatística [http://www.fee.rs.gov.br].
[j]Official data available for 2014. Source: Fundação de Economia e Estatística [http://www.fee.rs.gov.br].
[k]Paediatric and neonatal intensive care beds.
[l]Economic data for 1993 should be interpreted with caution due as hyperinflation was taking place during this year (annual inflation ratio of 2477.2%).

in particularly of hospital beds, was substantially reduced, particularly due to the shift in psychiatric care from inpatient to outpatient care. The number of public sector primary care units increased from 37 to 54. Of particular interest for the cohorts is the fact that whereas in 1982 there were no neonatal or paediatric intensive care units, 16 beds were available in 2015, 19 in 2004 and 29 in 2015.

There were major changes in the organization of health services in Brazil and in Pelotas throughout the study period. In 1982, services presented the tradition three-tier system that was common in Latin America: private care, the National Social Security Institution for regularly employed citizens and their families, and the indigent category. The latter included the poorest strata of the population who could not afford private care and were not regularly employed; it included 5.6% of all women in the 1982 cohort. In 1988, the National Health System was created, a tax-based universal system that covers the whole population. Yet substantial proportions of families, although entitled to the National Health System, prefer to take out private insurance where care is perceived as being better, and access to consultations and examinations is faster. In 2015, 45% of the women studied belonged to the private insurance system; it should be noted that many of these private plans do not cover for hospital admissions, so that 68% of all women who gave birth were covered by the National Health Service. The Supplementary Table, available as Supplementary data at *IJE* online shows the proportions of births in the four cohorts according to hospital and type of payment for delivery.

Table 2 presents trends in child, maternal, paternal and household characteristics from 1982 to 2015. Except for 1993, more boys than girls were born. There was a constant decline in the proportion of white mothers, from 82.1% in 1982 to 71.9% in 2015. A similar decline was observed for paternal skin colour for the three cohorts when this information was collected. The proportions of single mothers increased from 8.2% to 14.2%, respectively.

Overall, during the 33-year period, mothers became older, although the proportion of adolescent mothers remained stable at around 15%. The percentage of mothers aged ≥30 years increased from about 25% in 1982 to almost 40% in 2015. Paternal age also increased from 1993 to 2015. Maternal schooling increased considerably; mean values were 6.5 (SD 4.2) years in 1982, 6.7 (SD 3.6) in 1993, 8.1 (SD 3.5) in 2004 and 10.1 (SD 4.0) in 2015. The percentage of mothers with <4 years of schooling declined from 21.7% in 1982 to 4.1% in 2015. Conversely, the proportion with ≥12 years of schooling increased from 14.2% in 1982 to 31.1% in 2015. Similar patterns were documented for paternal schooling, with the proportion with <4 years falling from 19.5% to 5.3%, respectively. The proportion of families earning one or less minimum wage per month declined from 21.9% in 1982 to 12.6% in 2015. The division of the sample into quintiles naturally resulted in roughly equal groups in all cohorts, each with about 20% of the sample (these numbers are presented because they provide the denominators for several analyses in other articles in this supplement). Household characteristics also changed considerably over time. Information on crowding was available for 2004 and 2015, showing a reduction from 21.2% to 13.9% in families with six or more members, and a corresponding reduction in the proportion of homes with more than two persons per bedroom. Treated water was available in 95.3% of households in 1982 and in 99.28% in 2015. Three-quarters of the families had a refrigerator at home in 1982, compared with 98.3% in 2015, and television ownership became practically universal.

Involvement of the women in the labour market became more common with time. In the 1982 cohort, 26.2% of the women worked in the formal or informal sector during the child's first year of life. This proportion increased 37.1% in 1993, 39.4% in 2004 and 48.3% in 2015.

Income-related inequalities in maternal age, schooling, household size, appliances and access to treated water are presented in Table 3, which also shows the summary indices for absolute (slope index) and relative (concentration index) inequalities. Both indices range from -100 to +100, with zero representing complete equality. Negative values indicate that the outcome is more frequent among the poor, whereas positive indices indicate higher frequency among the rich. Teenage mothers were proportionately about five times more common in the poorest than in the richest quintile in 1982, and six times more common in 2015, so that inequalities increased slightly over time. In contrast, the proportion of mothers aged ≥35 years remained stable in the poorest quintile but more than doubled in the richest, leading to sharp increases in inequality. Income-related gaps in low maternal schooling (<4 years) were markedly reduced in absolute, but not in relative terms. Absolute inequalities in television and refrigerator ownership, and in having untreated water, also fell markedly.

Table 4 shows trends in maternal and household characteristics according to maternal skin colour. The proportion of adolescent mothers was higher among black or brown mothers in all years except for 2004, but the proportion of mothers aged ≥35 years only increased over time among Whites. Low maternal schooling (<4 years) was reduced in all skin colour groups, but differences were still marked as of 2015. Households with six or more members were twice as common for black or brown compared with for white women in the two latest cohorts, when data were available. Gaps in television and refrigerator ownership and in access to treated water were eliminated as universal coverage was reached.

Discussion

The present article is the first in a series of 10 publications reporting on time trends and inequalities in indicators related to pregnancy, delivery and the first year of life in four birth cohorts spanning 33 years. Our series is one of the few in world with prospective, population-based data collection using similar methods over such a long period of time. The existence of four cohorts allows longitudinal analyses of developmental origins of health and disease, as well as comparisons of how maternal and child indicators have evolved over time. The present supplement is focused on the second type of analysis, with special attention to wealth-related and ethnic group inequalities, which have been and remain key drivers of health conditions in Brazil, one of the least egalitarian countries in the world.[29]

The cohorts span a period of rapid transformation in Brazilian society, with positive trends consisting of a reduction in poverty and in fertility, massive declines in infectious diseases and in infant mortality, urbanization and the

Table 2. Sample characteristics according to birth cohort

Variables	Cohort perinatal sample, *n* (%)				*P*
	1982	1993	2004	2015	
Sex					0.948
Males	3037 (51.4)	2603 (49.6)	2196 (51.9)	2164 (50.6)	
Females	2876 (48.6)	2645 (50.4)	2035 (48.1)	2111 (49.4)	
Maternal skin colour					<0.001
White	4851 (82.1)	4058 (77.3)	3090 (73.0)	3071 (71.9)	
Brown	–	234 (4.5)	295 (7.0)	561 (13.1)	
Black	1060 (17.9)[c]	955 (18.2)	846 (20.0)	639 (15.0)	
Paternal skin colour					<0.001
White	–	4064 (77.9)	2709 (66.3)	2983 (71.4)	
Brown	–	256 (4.9)	793 (19.4)	541 (13.0)	
Black	–	899 (17.2)	583 (14.3)	653 (15.6)	
Marital status					<0.001
Single mother	485 (8.2)	649 (12.4)	695 (16.4)	607 (14.2)	
With partner	5424 (91.8)	4600 (87.6)	3536 (83.6)	3667 (85.8)	
Maternal age (years)					<0.001
12–19	912 (15.4)	915 (17.4)	800 (18.9)	622 (14.6)	
20–24	1843 (31.2)	1447 (27.6)	1149 (27.2)	1011 (23.6)	
25–29	1599 (27.0)	1353 (25.8)	959 (22.7)	1006 (23.5)	
30–34	973 (16.5)	956 (18.2)	758 (17.9)	1003 (23.5)	
≥35	586 (9.9)	577 (11.0)	563 (13.3)	632 (14.8)	
Paternal age (years)					<0.001
13–19	–	302 (5.8)	308 (7.4)	256 (6.1)	
20–24	–	1194 (23.1)	970 (23.4)	843 (20.1)	
25-29	–	1340 (25.9)	994 (24.0)	901 (21.5)	
30-39	–	1815 (35.1)	1366 (33.0)	1703 (40.5)	
≥40	–	517 (10.0)	503 (12.2)	498 (11.9)	
Maternal schooling (years)					<0.001
<4	1282 (21.7)	832 (15.9)	348 (8.3)	173 (4.1)	
4-8	3132 (53.0)	3060 (58.4)	2038 (48.7)	1313 (30.7)	
9-11	654 (11.1)	923 (17.6)	1382 (33.0)	1458 (34.1)	
≥12	839 (14.2)	427 (8.2)	420 (10.0)	1330 (31.1)	
Paternal schooling (years)					<0.001
<4	266 (19.5)	732 (15.1)	318 (9.7)	213 (5.3)	
4–8	727 (53.4)	2863 (59.0)	1423 (43.3)	1469 (36.9)	
9-11	174 (12.8)	908 (18.7)	1181 (35.9)	1258 (31.6)	
≥12	194 (14.3)	352 (7.3)	364 (11.1)	1043 (26.2)	
Family income (minimum wages)					<0.001
≤1	1288 (21.9)	967 (18.8)	897 (21.2)	538 (12.6)	
>1–3	2789 (47.4)	2148 (41.8)	1939 (45.8)	2014 (47.1)	
>3–6	1091 (18.5)	1204 (23.4)	945 (22.3)	1127 (26.4)	
>6-10	382 (6.5)	433 (8.4)	243 (5.7)	324 (7.6)	
>10	335 (5.7)	385 (7.5)	207 (4.9)	270 (6.3)	
Family income (quintiles)					0.867
Q1 (poorest)	1183 (20.0)	1031 (20.1)	872 (20.6)	846 (19.8)	
Q2	1178 (19.9)	1195 (23.3)	855 (20.2)	859 (20.1)	
Q3	1180 (20.0)	889 (17.3)	816 (19.3)	853 (20.0)	
Q4	1185 (20.0)	1001 (19.5)	858 (20.3)	856 (20.0)	
Q5 (richest)	1188 (20.1)	1021 (19.9)	830 (19.6)	859 (20.1)	
Household members					<0.001
≤3	–	–	1197 (30.0)	1545 (37.7)	
4–5	–	–	1943 (48.8)	1990 (48.5)	
≥6	–	–	845 (21.2)	569 (13.9)	

(Continued)

Table 2. Continued

Variables	Cohort perinatal sample, *n* (%)				*P*
	1982	1993	2004	2015	
Household crowding (persons/bedroom[a])					<0.001
≤2	–	–	1250 (31.4)	1678 (40.9)	
>2	–	–	2735 (68.6)	2425 (59.1)	
Treated water					<0.001
No	234 (4.7)	49 (3.5)	39 (1.0)	33 (0.8)	
Yes[b]	4757 (95.3)	1365 (96.5)	3945 (99.0)	4240 (99.2)	
Television					<0.001
No	668 (13.3)	183 (12.8)	163 (3.9)	34 (0.8)	
Yes	4338 (86.7)	1231 (87.2)	4066 (96.2)	4236 (99.2)	
Refrigerator					<0.001
No	1235 (24.7)	375 (25.7)	458 (10.8)	72 (1.7)	
Yes	3771 (75.3)	1039 (74.3)	3771 (89.2)	4198 (98.3)	
Total	5914	5249	4231	4275	

[a]Number of bedrooms = bedrooms used for sleeping.
[b]Treated water = source of piped water indoors or on the ground.
[c]Brown and black combined in 1982.
P-value: χ^2 test for trend.

creation of a national health service (the Sistema Único de Saúde or SUS).[7] Many of these trends are reflected in the sociodemographic characteristics described here. These include important increases in parental education, family income and availability of safe water and household appliances. Reduced fertility led to smaller families and to a marked drop in the city birth rate, from 23 to 13 births per thousand inhabitants over the 33-year period. This was accompanied by an important increase in the percentage of mothers aged ≥35 years, as childbearing was postponed among the rich. Poverty reduction was part of a national trend; the inflation-adjusted value of the minimum wage increased, and at the same time the proportion of families earning less than one minimum wage declined. It should be noted, however, that poverty reduction in Pelotas was not as rapid as for the country as a whole. Whereas in 1982 the city's gross domestic product was 9% above the national mean, by 2015 it was 26% lower (Table 1). This may explain why local improvements in the health of mothers and children were not, in some instances, as marked as those observed for the rest of Brazil. Such comparisons will be presented in the next articles in this supplement.

Since 1988, the Pelotas cohorts have had a strong focus on health inequalities.[30] The comparison of the four cohorts shows that absolute disparities associated with family wealth were greatly reduced over time for characteristics such as parental schooling and household conditions. For some indicators where prevalence was close to zero in the richest quintile—such low education, untreated water or lack of television or refrigerator—the declines in absolute inequalities were not always consistent with declines in relative inequalities, as the latter are highly sensitive to low values in the better-off group. Such apparent paradoxical results are not unusual in the literature on time trends in inequalities. This is why it is important to report on both absolute and relative inequalities, and to allow readers to reach their own interpretation.[31] In contrast to indicators for which inequalities declined, the proportion of teenage mothers according to income groups became slightly less equitable over time with an increase among the poor, whereas the proportion of mothers aged ≥35 years remained stable among the poor but increased sharply among the rich, reflecting delayed childbearing in the latter group, likely associated with educational achievements and career choices.[32]

We also focused on ethnic group inequalities. The main economic activity in Pelotas in the 1800s was the manufacture of sun-dried beef or 'jerky'. Cattle from the Pampas region were brought to Pelotas where they were slaughtered and their meat was dried, and then shipped to Rio de Janeiro, São Paulo and other populous areas in Brazil. African slaves were brought to Pelotas in large numbers to provide the intense manual labour involved in this industry.[33]

As a consequence, Pelotas is one of the cities in Southern Brazil with the highest proportion of Afro-descendants, who in the 2015 cohort represented almost 30% of all women who gave birth. Because of the marked miscegenation that characterizes our population, the proxy for ethnicity used in national censuses and surveys is self-reported skin colour. This classification is endorsed by the

Table 3. Maternal and household characteristics according to quintiles of family income

	Family income (quintiles) % (95% CI)							
	Q1	Q2	Q3	Q4	Q5	*P*-value[a]	Slope index of inequality (95% CI)	Concentration index (95% CI)
Maternal age ≤19 years, *P*	0.330	0.001	0.002	0.176	0.446			
1982	26.1 (23.6–28.6)	15.4 (13.3–17.4)	18.9 (16.7–21.1)	11.1 (9.3–12.9)	5.6 (4.3–7.0)	<0.001	−22.4 (−25.6; −19.3)	−23.7 (−26.9; −20.6)
1993	22.0 (19.5–24.6)	22.6 (20.2–25.0)	15.6 (13.2–18.0)	16.9 (14.6–19.2)	8.0 (6.4–9.7)	<0.001	−15.1 (−18.6; −11.6)	−13.7 (−17.1; −10.4)
2004	28.3 (25.3–31.3)	24.3 (21.4–27.2)	20.0 (17.2–22.7)	13.1 (10.8–15.3)	8.6 (6.6–10.5)	<0.001	−25.0 (−29.0; −21.0)	−21.7 (−25.0; −18.5)
2015	26.4 (23.4–29.3)	20.8 (18.1–23.6)	12.0 (9.8–14.1)	9.6 (7.6–11.6)	4.2 (2.8–5.5)	<0.001	−27.8 (−31.5; −24.0)	−30.3 (−34.0; −26.6)
Maternal age ≥35 years, *P*	0.404	0.599	<0.001	<0.001	<0.001			
1982	8.0 (6.4–9.5)	12.5 (10.6–14.4)	7.2 (5.7–8.7)	9.7 (8.0–11.4)	12.2 (10.3–14.1)	0.036	2.8 (1.4; 5.5)	5.3 (0.8; 9.7)
1993	7.1 (5.5–8.7)	8.5 (6.9–10.0)	13.0 (10.8–15.3)	11.2 (9.2–13.1)	16.3 (14.0–18.5)	<0.001	9.7 (6.7; 12.6)	14.6 (10.3; 18.8)
2004	8.9 (7.0–10.7)	11.7 (9.5–13.9)	13.0 (10.7–15.3)	14.2 (11.9–16.6)	19.0 (16.4–21.7)	<0.001	11.3 (7.7; 14.9)	13.4 (9.0; 17.8)
2015	8.5 (6.6–10.4)	10.8 (8.7–12.9)	12.5 (10.3–14.8)	15.8 (13.3–18.2)	26.2 (23.3–29.2)	<0.001	19.9 (16.1; 23.8)	21.3 (17.2; 25.4)
Maternal schooling <4 years, *P*	<0.001	<0.001	<0.001	<0.001	<0.001			
1982	46.2 (43.3–49.0)	41.6 (38.8–44.4)	10.2 (8.4–11.9)	8.5 (6.9–10.1)	2.1 (1.3–2.9)	<0.001	−59.0 (−62.1; −56.0)	−44.1 (−46.2; −42.1)
1993	31.4 (28.6–34.2)	18.4 (16.2–20.6)	13.8 (11.5–16.0)	9.0 (7.2–10.8)	4.3 (3.0–5.6)	<0.001	−28.6 (−32.3; −25.0)	−29.2 (−32.6; −25.8)
2004	16.1 (13.7–18.6)	11.6 (9.4–13.7)	8.0 (6.1–9.9)	4.3 (3.0–5.7)	1.0 (0.2–1.5)	<0.001	−19.5 (−22.7; −16.4)	−36.7 (−41.3; −32.0)
2015	9.5 (7.5–11.4)	5.8 (4.3–7.4)	3.4 (2.2–4.6)	1.4 (0.6–2.2)	0.2 (0.0–0.6)	<0.001	−12.2 (−14.7; −9.6)	−48.1 (−54.1; −42.0)
Number of household members ≥6, *P*	<0.001	<0.001	<0.001	0.003	<0.001			
1982	–	–	–	–	–		–	–
1993	–	–	–	–	–		–	–
2004	26.5 (23.3–29.5)	24.8 (21.8–27.7)	20.8 (18.0–23.7)	18.8 (16.1–21.4)	15.1 (12.5– 17.6)	<0.001	−14.1 (−18.5; 9.8)	−10.0 (−13.5; −6.6)
2015	17.9 (15.3–20.6)	16.4 (13.9–19.0)	12.8 (10.5–15.0)	13.3 (11.0–15.7)	8.8 (6.9–10.8)	<0.001	−10.3 (−14.0; −6.7)	−12.3 (−16.7; −8.0)
Families with no television, *P*	<0.001	<0.001	<0.001	<0.001	0.009			
1982	33.9 (30.9–37.0)	16.7 (14.4–19.1)	11.2 (9.2–13.1)	5.4 (4.1–6.8)	1.0 (0.4–1.6)	<0.001	−39.0 (−42.5; −35.5)	−44.2 (−47.3; −41.2)
1993	31.2 (25.8–36.6)	15.0 (11.2–18.8)	10.3 (6.5–14.0)	3.8 (1.5–6.2)	1.6 (0.0–3.1)	<0.001	−35.4 (−42.2; −28.7)	−42.3 (−49.3; −36.5)
2004	9.9 (7.9–11.8)	4.8 (3.4–6.2)	2.8 (1.7–4.9)	1.3 (0.5–2.0)	0.2 (0.0–0.5)	<0.001	−12.4 (−15.1; −9.8)	−49.0 (−55.2; −42.8)
2015	1.2 (0.5–1.9)	1.3 (0.5–2.0)	0.6 (0.0–1.1)	0.7 (0.1–1.3)	0.2 (0.0–0.6)	0.010	−1.2 (−2.2; −0.1)	−24.3 (−41.9; −6.7)
Families with no refrigerator, *P*	<0.001	<0.001	<0.001	<0.001	<0.001			
1982	56.3 (53.2–59.5)	35.1 (32.1–38.1)	22.9 (20.3–25.5)	9.2 (7.4–10.9)	2.3 (1.4–3.3)	<0.001	−62.6 (−65.7; −59.6)	−42.3 (−44.4; −40.2)
1993	55.1 (49.3–60.9)	32.0 (27.0–36.9)	22.1 (17.0–27.3)	13.8 (9.6–18.1)	4.8 (2.1–7.4)	<0.001	−55.3 (−61.8; −48.8)	−34.5 (−38.9; −30.1)
2004	27.2 (24.3–30.2)	15.3 (12.9–17.7)	7.5 (5.7–9.3)	2.4 (1.4–3.5)	1.0 (0.3–1.6)	<0.001	−35.4 (−39.1; −31.6)	−48.5 (−52.0; −45.0)
2015	3.8 (2.5–5.1)	2.2 (1.2–3.2)	1.2 (0.4–1.9)	0.8 (0.2–1.4)	0.5 (0.0–0.9)	<0.001	−4.1 (−5.7; −2.5)	−34.9 (−46.4; −23.4)
Untreated water, *P*	<0.001	<0.001	<0.001	<0.001	0.666			
1982	11.1 (9.1–13.1)	6.6 (5.1–8.1)	3.8 (2.6–5.0)	2.0 (1.2–2.9)	0.5 (0.0–0.9)	<0.001	−13.3 (−15.8; −10.8)	−41.5 (−47.1; −36.0)
1993	9.1 (5.8–12.5)	3.2 (1.3–5.1)	2.8 (0.7–4.8)	1.2 (0.0–2.5)	0.4 (0.0–1.2)	<0.001	−9.9 (−14.4; −5.5)	−46.0 (−59.5; −32.5)
2004	2.3 (1.3–3.4)	1.4 (0.6–2.2)	0.9 (0.2–1.6)	0.1 (0.0–0.4)	0.1 (0.0–0.4)	<0.001	−2.9 (−4.2; −1.7)	−48.6 (−61.9; −35.3)
2015	0.7 (0.1–1.3)	1.7 (0.9–2.6)	0.7 (0.1–1.3)	0.2 (0.0–0.6)	0.5 (0.0–0.9)	0.034	−1.0 (−1.9; −0.1)	−22.6 (−40.1; −5.1)

P-values for inter-cohorts chi-square test for trend.
[a] *P*-values for intra-cohort chi-square test for trend.

Table 4. Maternal and household characteristics according to skin colour

	Skin colour % (95% CI)			
	Black	Brown	White	*P*-value[a]
Maternal age ≤ 19 years, *P*	0.127*		0.100	
1982	17.4 (15.1-19.6)		15.0 (14.0-16.0)	0.055
1993	20.3 (17.8-22.9)	20.9 (15.7-26.1)	16.6 (15.4-17.7)	0.008
2004	19.3 (16.6-21.9)	18.3 (13.9-22.7)	18.9 (17.5-20.3)	0.931
2015	20.3 (17.2-23.5)	20.9 (17.5-24.2)	12.2 (11.0-13.4)	<0.001
Maternal age ≥35 years, *P*	0.376*		<0.001	
1982	11.1 (9.2-13.0)		9.6 (8.8-10.5)	0.143
1993	10.9 (8.9-12.9)	10.3 (6.4-14.2)	11.1 (10.1-12.0)	0.922
2004	12.2 (10.0-14.4)	15.3 (11.1-19.4)	13.4 (12.2-14.6)	0.376
2015	13.0 (10.4-15.6)	10.2 (7.7-12.7)	16.0 (14.7-17.3)	0.001
Maternal schooling <4 years, *P*	<0.001*		<0.001	
1982	34.1 (31.2-36.9)		19.0 (17.9-20.1)	<0.001
1993	23.2 (20.6-26.0)	24.4 (18.8-29.9)	13.6 (12.6-14.7)	<0.001
2004	12.2 (10.0-14.4)	11.9 (8.2-15.7)	6.9 (6.0-7.8)	<0.001
2015	8.8 (6.6-11.0)	6.2 (4.2- 8.2)	2.7 (2.1-3.2)	<0.001
Number of household members ≥6, *P*	<0.001*		<0.001	
1982	–		–	–
1993	–	–	–	–
2004	34.4 (31.2-37.8)	19.6 (15.0-24.3)	17.8 (16.4-19.2)	p < 0.001
2015	24.2 (20.8-27.6)	18.9 (15.6-22.2)	10.8 (9.7-11.9)	p < 0.001
Families with no television, *P*	<0.001*		<0.001	
1982	23.6 (20.8-26.4)		11.1 (10.1-12.1)	<0.001
1993	20.2 (16.4-28.1)	20.7 (10.3-31.1)	10.3 (8.3-12.2)	<0.001
2004	5.7 (4.1-7.2)	5.8 (3.1-8.4)	3.2 (2.6-3.8)	0.001
2015	0.6 (0.0-1.2)	1.1 (0.2-1.9)	0.7 (0.4- 1.1)	0.656
Families with no refrigerator, *P*	<0.001*		<0.001	
1982	42.2 (38.9-45.4)		20.9 (19.6-22.1)	<0.001
1993	38.9 (32.1-46.7)	40.9 (28.4-53.5)	22.0 (19.3-24.6)	<0.001
2004	18.0 (15.4-20.6)	18.6 (14.2-23.1)	8.1 (7.2-9.1)	<0.001
2015	2.5 (1.3-3.7)	2.0 (0.8-3.1)	1.5 (1.0-1.9)	0.156
Untreated water, *P*	<0.001*		<0.001	
1982	6.8 (5.1-8.4)		4.2 (3.6-4.8)	0.001
1993	2.4 (0.4-4.3)	10.8 (2.7-18.9)	3.2 (2.1-4.3)	0.057
2004	1.4 (0.6-2.2)	2.5 (0.7- 4.3)	0.7 (0.4-1.0)	0.006
2015	0.5 (0.0-1.0)	0.9 (0.1-1.7)	0.8 (0.5-1.1)	0.626

P-values for inter-cohorts chi square test for trend.
[a]*P*-values for intra-cohort chi-square test.
**P*-values for black or brown combined into a single category in 1993, 2004 and 2015, allowing comparison with 1982.

black movement, which advocates for disaggregation of all relevant national statistics in order to raise the visibility of Afro-descendants.[18] In our cohorts, the proportion of brown or black women giving birth increased from 18% to 28% over time. It is unclear whether this was due to changes in the way this variable was ascertained (according to the interviewer in 1982 and 1993, and through self-report in 2004 and 2015), to differential fertility rates over time, and/or to increased visibility of the black movement leading to greater recognition of African ancestry.

Despite the methodological limitations associated with measurement of ethnicity over the four cohorts, disparities are evident. For example, adolescent childbearing, low maternal schooling and household crowding are more prevalent among Afro-descendants, whereas late childbearing prevails among Whites. These findings justify the need for disaggregating health statistics according to skin colour, and for designing public policies that allow Afro-descendant women and children the same living conditions and access to education and health that is enjoyed by white women and children.

It is important to highlight that the data presented here are not necessarily representative of Brazil as a whole. However, the present findings could have important implications for the country and other middle-income countries facing demographic transition, and where public and private sectors coexist. To assess the external validity of our cohort findings, we have a strong collaboration with other cohorts from low- and middle-income countries (Guatemala, India, the Philippines and South Africa) which has generated tens of publications on the long-term consequences of under-nutrition,[34] as well as with other Brazilian cohorts.[35] We have also collaborated with cohorts from high-income countries, including the United Kingdom, The Netherlands and Belarus,[5,36] mainly in order to improve causal inference through cross-cohort comparisons, and joined multisite studies on genetic epidemiology.[37–40]

One limitation of this study, which is common in birth cohorts, has been attrition rates in the follow-up visits. However, except for the 12-month visit of the 1982 cohort, in which we could not trace 20.7% of the children, we located at least 90% of all children in all other visits. Losses in 1982 were more frequent among the poorest and the richest strata of the population, as middle-class families were more easily found.[25] Another limitation inherent in this type of study is that data collection is based primarily on self-reports, mostly from the mother during the life period covered in this article. Given changes in medical practice over time, gestational age was ascertained with different methods in the early and late cohorts, and there were also differences in how weight at the end of the pregnancy was measured; these discrepancies are described in the articles on specific outcomes in this supplement.

Thus, data on morbidity during pregnancy, antenatal care, labour induction, infant morbidity etc. are based on what is stated by the interviewee. The quality of this information is variable and depends on characteristics relating to the interviewee (such as age and schooling), and on the type of information (personal, medical). The possibility of information error affecting the results of specific analyses is discussed in each article. On the other hand, the cohort strategy allows for this information to be collected close to its occurrence, thus minimizing recall bias.

Yet another limitation is that the 1993 cohort study took place during a period of hyperinflation. According to the National Consumer Price Index, whereas annual inflation in 1982 was 104.8%, 7.6% in 2004 and 10.7% in 2015, in 1993 annual it reached 2477.2%, which may introduce noise in the income data collected in that year.[41] Hyperinflation ended in mid-1994, when a new economic plan was introduced and turned the currency into 'Real', which is still in use in the country.[42]

In the present article, we provide background information on the methodology of the four Pelotas cohorts and a general description of sociodemographic and environmental conditions of the families included, with emphasis on social and ethnic inequalities. The information presented here will contribute to the interpretation of time trends and disparities in maternal and child health outcomes, which will be presented in the following eight articles included in the supplement.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Center, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centers of Excellence (PRONEX), Brazilian National Council for Scientific and Tehcnological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child and Brazilian Association for Collective Health (ABRASCO).

Acknowledgements

Cesar Tejada (Federal University of Pelotas); Franciele Hellwig (Federal University of Pelotas), Elaine Albernaz (Catholic University of Pelotas).

Pelotas Cohorts Study Group

Ana M B Menezes,[1] Alicia Matijasevich,[2] Diego Bassani,[3] Fernando C Wehrmeister,[1] Iná S Santos,[1] Maria Cecilia F Assunção,[1] Mariangela F Silveira[1] and Marlos Rodrigues Domingues.[1]
[1]Federal University of Pelotas, Brazil, [2]University of São Paulo, Brazil and [3]University of Toronto, Canada.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i80–i88
doi: 10.1093/ije/dyy233
Supplement Article

Supplement Article

Infant nutrition and growth: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Helen Gonçalves ,[1] Fernando C Barros,[2] Romina Buffarini,[1] Bernardo L Horta ,[1] Ana M B Menezes ,[1] Aluísio J D Barros ,[1] Marlos R Domingues ,[1] Cesar G Victora [1]* and the Pelotas Cohorts Study Group**

[1]Post Graduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil and [2]Post Graduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

*Corresponding author. Federal University of Pelotas, Rua Marechal Deodoro, 1160 – 3o. Piso, CEP 96083-080 Pelotas, RS, Brazil. E-mail: cvictora@gmail.com
**Members listed at end of article.

Editorial decision 19 September 2018; Accepted 8 October 2018

Abstract

Background: Levels of child undernutrition have declined in many middle-income countries, whereas overweight and obesity have increased. We describe time trends in nutritional indicators at age 1 year in the 1982, 1993, 2004 and 2015 Pelotas (Brazil) Birth Cohorts.
Methods: Each study included all children born in the urban area of the city, with over 4 200 births in each cohort. Children were measured at approximately 12 months of age. Anthropometric indicators were calculated according to World Health Organization Growth Standards. Stunting and wasting were defined as <-2 Z scores for length for age and weight for length, and overweight as >2 Z scores for weight for length. Prevalence was stratified by sex, maternal skin colour and family income.
Results: The prevalence of stunting declined by 53% (from 8.3% to 3.9%) from 1982 to 2015. Wasting prevalence remained stable at low levels (1.8% in 1982 and 1.7% in 2015), whereas overweight increased by 88% (6.5% to 12.2%). Undernutrition was more common among boys, those born to mothers with brown or black skin colour and in the poorest quintile of families. Socioeconomic inequalities in undernutrition decreased markedly over time. Overweight was markedly more common among the rich in 1982, but fast increase among the poor eliminated socioeconomic differences by 2015, when all groups showed similar prevalence.
Conclusions: Our results confirm the rapid nutrition transition in Brazil, with marked reduction in levels and inequalities in undernutrition in parallel with a rapid increase in overweight, which became the main nutritional problem for children.

Key words: Infant nutrition disorders, birthweight, body height, anthropometry, socioeconomic factors, Cohort studies

Key Messages

- Stunting prevalence declined from 8.3% in 1982 to 3.9% in 2015, a reduction of 53% overall, being faster (70%) in the poorest quintile than among the richest (11%).
- Wasting prevalence was below 2% in all four cohorts (no clear reason for apparent increase in 2015 when it reached 1.7% compared with 0.6% in 1993 and 2004), with a 50% reduction among the poor and children with Black or Brown mothers.
- Boys presented higher prevalence than girls for stunting (40% higher), wasting (30%) and overweight (20%).
- Overweight prevalence increased by 88% between 1982 and 2015, with a particularly fast increase after 2004; over time, the increase in the poorest quintile was equal to 63% compared with 22% among the richest.
- The current prevalence of stunting in Pelotas is over twice times, and that of underweight over five times, higher than the 2.3% that would be expected in a well-nourished population.

Introduction

Child malnutrition may result from either undernutrition, overweight or micronutrient deficiencies.[1] Undernutrition in early life has well-known short-term consequences, particularly the higher severity and mortality of infectious diseases,[2] as well as the long-term impact on human capital including shorter adult height, reduced reproductive capacity, lower intelligence and attained schooling and reduced adult income and productivity.[3] Childhood undernutrition followed by rapid weight gain in adolescence or adulthood has also been linked to higher risks of non-communicable diseases.[3] Recently, there has been growing concern with childhood overweight, as it is a strong predictor of excessive weight and of cardiovascular and metabolic diseases in later life.[4–6]

Stunting (height-for age deficit),[6–9] underweight (weight-for-age deficit) and wasting (weight-for-height deficit) rates are decreasing globally, whereas prevalence of overweight (high weight-for-height) and obesity is increasing.[1,5,10] About 24% of the world's children under the age of 5 years are stunted, 7.5% are wasted and 6.1% overweight.[9] The highest prevalences of stunting and wasting are observed in low- and middle-income countries (LMICs). Stunting prevalence is declining in many countries, where overweight is increasing.[9]

Nationally representative estimates of child nutrition are not available for Brazil since 2007. Analyses of national trends showed massive reductions in stunting—from 37% in 1974–75 to 7% in 2006–07—and in underweight.[11] National surveys carried out up to 2007 do not show an increase in overweight prevalence among under-five children,[11] but other data sources suggest that prevalence in the 5–19 years age range is increasing rapidly.[5]

The complex interplay of social, economic and political determinants of undernutrition results in substantial inequalities between population subgroups.[1] LMICs consistently show socioeconomic inequalities in the prevalence of stunting, which is concentrated in the poorest wealth quintile.[1,12,13] In contrast, differences in childhood overweight prevalence between the richest and poorest quintiles are small in most countries.[1,2]

We report on time trends in the prevalence of stunting, wasting and overweight at the age of 1 year, in four population-based birth cohort studies carried out in the city of Pelotas in Southern Brazil between 1982 and 2015, with special attention to inequalities according to socioeconomic status, maternal skin colour and sex of the child. Our analyses update a previous report published in 2008, which described time trends up to 2004.[12]

Methods

Four population-based birth cohort studies were carried out in the city of Pelotas in Southern Brazil (approximate current population of 340 000) in 1982, 1993, 2004 and 2015. In each year, all mothers of hospital-delivered newborns, who resided in the urban area of the city, were invited to participate in the studies. Data were collected on 5914; 5245; 4231; and 4275 live births, respectively. Hospital births account for over 99% of all city deliveries, and refusal rates at recruitment were below 2% in the four cohorts. Participants of the four cohorts have been followed up on several occasions since birth, initially at home and since 2009 at a purpose-built research facility. Further details of the methodology are available elsewhere.[14]

All cohorts included visits around the age of 12 months. The 1982 cohort subsample included all infants who were born from January to April 1982 ($n = 1, 916$). In the 1993 cohort, all low birthweight (<2500 g) children plus a 20% systematic sample of all other newborns were included ($n = 1, 460$). In the 2004 and 2015 cohorts, the visits included the full cohorts.[15,16]

In the 1982, 1993 and 2004 cohorts, supine length was measured using locally built infantometers with 1-mm precision (AHRTAG, London, UK), custom-built for these studies.[13–15] In the 2015 cohort, length was assessed using a SANNY ES2000 portable anthropometer (SANNY, Brazil) with 5-mm precision.[15] Weight was evaluated using Salter CMS mechanical scales with 25-kg maximum and 100-g precision (Salter, Tonbridge, UK) in the 1982 and 1993 cohort. Scales were calibrated weekly with standard weights.[17] In 2004, the mothers were initially weighed using Tanita electronic scales (Tanita, Tokyo, Japan) with a 150-kg maximum and 100-g precision; next, they held the child in their laps and their joint weight was recorded. The child's weight was calculated in the data analyses phase, as the difference between the two measurements.[15] In the 2015 cohort, the mother and the child were first weighed together using a TANITA UM80 scales (TANITA, Japan) with 100-g precision; the mother then handed the child to the interviewer, and her weight was measured. The child's weight was calculated automatically by the scale as the difference between the two weights.[15] In all four cohorts, children were weighed without any clothes and about 10% of all measurements were repeated by supervisors for quality control purposes.

Length-for-age, weight-for-length and weight-for-age Z-scores were calculated according to the World Health Organization Growth Standards (WHO 2006), using Anthro 2005 software [http://www.who.int/childgrowth/software/en/]. Stunting, wasting and underweight were defined as less than -2 standard deviations (SD) or Z scores of length-for-age, weight-for-length and weight-for-age, respectively. Children with Z scores of weight-for-length above +2 were classified as overweight.[18]

Independent variables included the child's sex, maternal skin colour and family income. Skin colour was observed by the interviewers in 1982 and classified as white or other; in 1993, colour was also observed and classified as white, brown or black. These three categories were also used in 2004 and 2015, but the information was based on self-report by the woman. The classification of skin colour is based on the recommendations of the Brazilian Census Bureau.[19] Family income was obtained by summing the monthly wages of all family members—defined as all persons living in the household and sharing meals—and later dividing this continuous variable into quintiles. Further information on these variables is available in the initial article of this Supplement.[14]

Chi square tests for heterogeneity were used to compare the prevalence of outcomes between categories of the exposure variable in each cohort, and chi square tests for linear trends were used to assess changes over time, from 1982 to 2015. As measures of health disparity, we used the slope index of inequality and concentration index to assess income-related inequality.[20] Time trends were assessed through interaction terms between the explanatory variables and the cohort year (fitted as an ordinal variable starting with 1982) using Poisson regression with robust variance with stunting, wasting and overweight as outcomes. When there was no statistical evidence of interaction, pooled prevalence ratios of the outcomes according to explanatory variables, after adjustment for cohort year, were presented.[21] In case of interaction, we presented prevalence ratios separately for each cohort. Presence of an interaction indicates that the prevalence ratio associated with one of the exposures is changing over time, that is relative inequality is changing.

All analyses using data of the 12-month follow-up of the 1993 cohort were weighted to correct for the oversampling of low birthweight, by assigning a sampling weight of 0.2 to the latter. All the analyses were performed using the software Stata version 12.1.[22]

Ethical approval for studies was not required in Brazil until 1996. In 1982 and 1993, verbal consent was obtained from caregivers. The 2004 study was approved by the Ethics Committee of the School of Medicine and the 2015 study by the School of Physical Education, Federal University of Pelotas, and free and informed consent form was obtained from the mothers in both years.

Results

The proportions of cohort members measured in the 12-month follow-up visits were 79.3% in 1982, 93.4% in 1993, 94.2% in 2004 and 95.4% in 2015. There were important changes in all anthropometric outcomes over the study period (Figure 1).

Stunting prevalence declined from 8.3% in 1982 to 3.9% in 2015, a reduction of 53% (Table 1). In all cohorts, stunting tended to be more common among boys and infants belonging to poor families. Pooled prevalence rates for stunting were 1.4 [95% confidence interval (CI) 1.2; 1.6] higher for boys relative to girls, with no evidence of change over time ($P = 0.45$ for interaction with cohorts). There was also no evidence of a change in prevalence according to maternal skin colour across the four cohorts ($P = 0.67$), with infants born to Black or Brown mothers presenting 1.3 (95% CI 1.1; 1.6) times higher risk than those born to White mothers. The ratio in stunting

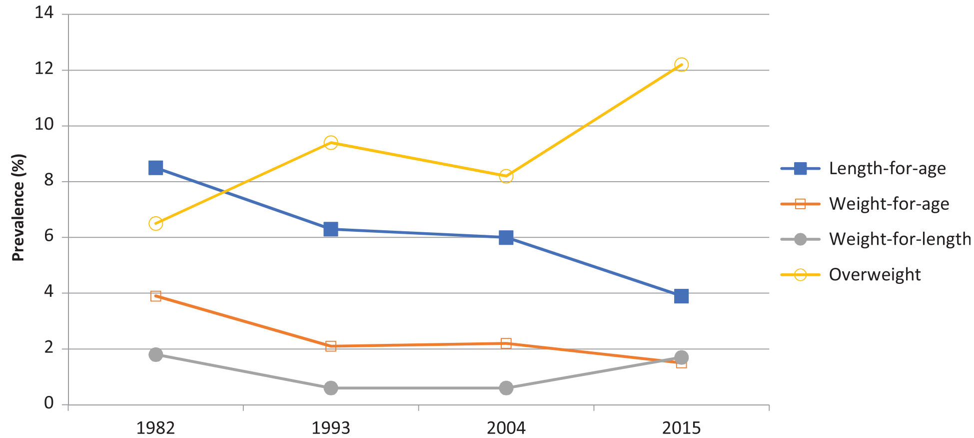

Figure 1. Prevalence of malnutrition (length-for-age, weight-for-age and weight-for-length deficits) and overweight at age 12 months in the 1982, 1993, 2004 and 2015 cohorts.

Table 1. Prevalence of stunting (<-2 Z scores of length-for-age) at age 12 months according sex, maternal skin colour and family income in the 1982, 1993, 2004 and 2015 cohorts

	1982		1993		2004		2015		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	P[a]
Sex	$P = 0.004$[b]		$P = 0.100$[b]		$P = 0.020$[b]		$P = 0.053$[b]		
Males	10.4	8.2; 12.9	7.4	5.5; 9.5	6.8	5.7; 8.0	4.5	3.7; 5.5	<0.001
Females	6.2	4.6; 8.2	5.3	3.9; 7.2	5.1	4.1; 6.2	3.3	2.6; 4.2	<0.001
Maternal skin colour	$P = 0.133$[b]		$P = 0.027$[b]		$P = 0.062$[b]		$P = 0.245$[b]		
White	7.7	6.3; 9.4	5.6	4.4; 7.2	5.4	4.6; 6.3	3.6	2.9; 4.4	<0.001
Brown	10.5[c]	7.1; 15.0	3.9	1.3; 11.5	6.7	4.0; 10.3	5.0	3.3; 7.3	<0.001
Black			10.0	6.6; 14.9	7.7	5.9; 9.8	4.5	2.9; 6.4	
Family income (quintiles)[b]	$P < 0.001$[b]		$P < 0.001$[b]		$P < 0.001$[b]		$P = 0.012$[b]		
Q1 (poorest)	18.7	13.8; 24.5	10.9	7.6; 15.4	8.1	6.3; 10.3	5.6	4.0; 7.5	<0.001
Q2	10.6	7.3; 14.6	8.4	5.8; 12.1	9.1	7.2; 11.4	5.2	3.7; 7.0	<0.001
Q3	6.0	3.6; 9.2	5.5	3.3; 9.1	5.7	4.2; 7.6	3.4	2.3; 5.0	<0.001
Q4	5.5	3.2; 8.7	2.5	1.3; 4.8	3.8	2.6; 5.4	2.4	1.5; 3.6	0.030
Q5 (richest)	3.6	1.8; 6.4	3.2	1.6; 6.5	3.1	2.0; 4.6	3.2	2.0; 4.9	0.767
All children	8.3	6.9; 9.8	6.3	5.1; 7.7	6.0	5.2; 6.8	3.9	3.3; 4.6	<0.001

[a]*P*-values are displayed from intercohorts chi square test.
[b]*P*-values are displayed from intracohort chi square test.
[c]Black and brown were combined.

prevalence between the poorest and richest quintile fell from 5.2 in 1982 to 1.8 in 2015, reflecting the decline of 70% among the poor, compared with only 11% among the rich. There was an interaction between income quintiles and cohort years ($P = 0.002$), which was confirmed by the marked reductions in absolute and relative inequalities over time according to the slope and concentration indices, respectively (Table 2).

Wasting prevalence was below 2% in the four cohorts (Table 3). There was no interaction between sex of the child and cohort year ($P = 0.99$); the pooled prevalence ratio for boys relative to girls was equal to 1.3 (95% CI 0.9; 1.8) (Supplementary Table 1, available as Supplementary data at *IJE* online). In contrast, there was statistical evidence that ethnic differences in wasting changed over time ($P = 0.001$); the prevalence ratios for black or brown skin colour, relative to white, were 4.6 (95% CI 2.2; 9.9), 3.6 (95% CI 1.0; 12.7), 1.5 (95% CI 0.7; 3.5) and 0.9 (95% CI 0.5; 1.6) in 1982, 1993, 2004 and 2015, respectively. For family income, prevalence was equal to zero in some of the wealthiest quintiles in 1982, 1993 and 2004. For this reason, we grouped the three richest quintiles for analyses and found evidence of an interaction with cohort year ($P = 0.008$). The prevalence ratios among the poorest relative to the three richest quintiles were 6.1 (95% CI 2.3; 15.7), 9.1 (95% CI 2.6; 31.4), 4.5 (95% CI 1.9; 11.1) and 1.5 (95% CI 0.8; 2.6), in the four cohort years, respectively. There was statistical evidence of an interaction with cohort year (Supplementary Table 1, available as Supplementary data at *IJE* online). Accordingly, the slope and concentration indices showed marked declines over time (Table 2). The joint prevalence of stunting and wasting was 0.7% (95% CI 0.2; 1.1) in 1982, 0.3% (95% CI 0.0; 0.6) in 1993 and 0.2% (95% CI 0.0; 0.3) in both 2004 and 2015.

Patterns and trends in underweight prevalence were very similar to those observed for stunting, with a reduction in overall levels and in inequalities related with skin colour and income (Table 4). The summary indices showed important reductions in inequality (Table 2). Overweight prevalence increased by 88% between 1982 and 2015, with a particularly fast upsurge after 2004 (Table 5). There was no statistical evidence of interactions between cohort year and either sex ($P = 0.17$) or skin colour ($P = 0.10$). In the pooled analyses, overweight was 1.2 (95% CI 1.1; 1.4) times more common among boys than girls, and the prevalence ratio for brown and black maternal skin colour relative to white was 0.9 (95% CI 0.8; 1.0) (Supplementary Table 1, available as Supplementary data at *IJE* online). Overweight was more prevalent among children from wealthy than from poor families in 1982 (prevalences of 9.5 in the richest quintile and 4.6 in the poorest quintile, Table 5), but the income gradient disappeared thereafter; there was no evidence of an interaction with cohort year ($P = 0.43$) (Supplementary Table 1, available as Supplementary data at *IJE* online). Over time, prevalence among the poorest showed a 2.7-fold increase, compared with a 1.3-fold increase in the richest quintile. The slope and concentration indices showed marked declines over time, confirming the reduction of inequalities (Table 2).

Table 2. Slope index of inequality and concentration index for the outcome variables according to family income quintiles, 1982, 1993, 2004 and 2015 cohorts

Outcome cohort	Slope index of inequality			Concentration index		
	β	SE	*P*	β	SE	*P*
Stunting						
1982	−16.0	2.9	<0.001	−30.5	4.8	<0.001
1993	−14.6	3.0	<0.001	−23.3	4.5	<0.001
2004	−7.6	1.4	<0.001	−21.1	3.4	<0.001
2015	−3.2	1.1	0.004	−13.8	4.7	0.003
Wasting						
1982	−5.6	1.5	<0.001	−50.6	7.8	<0.001
1993	−2.0	1.2	0.085	−31.7	13.9	0.024
2004	−1.5	0.5	0.004	−38.3	10.0	<0.001
2015	−1.0	0.7	0.202	−9.0	7.1	0.204
Overweight						
1982	5.5	2.4	0.023	15.9	5.9	0.007
1993	2.4	2.6	0.351	4.0	5.3	0.451
2004	0.8	2.0	0.587	1.4	3.1	0.643
2015	0.7	1.8	0.716	0.8	2.4	0.738

P levels reflect the probability that the index is different from zero (no inequality).

B, regression coefficient; SE, standard error.

Table 3. Prevalence of wasting (<-2 Z scores of weight-for-length) at age 12 months according sex, maternal skin colour and family income in the 1982, 1993, 2004 and 2015 cohorts

	1982		1993		2004		2015		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	P^a
Sex	$P = 0.400^b$		$P = 0.800^b$		$P = 0.400^b$		$P = 0.317^b$		
Males	2.1	1.2; 3.5	0.5	0.2; 1.2	0.7	0.4; 0.1	1.8	1.3; 2.5	0.920
Females	1.5	0.7; 2.6	0.7	0.3; 1.6	0.5	0.3; 1.0	1.4	1.0; 2.1	0.934
Maternal skin color	$P < 0.001^b$		$P = 0.005^b$		$P = 0.548^b$		$P = 0.547^b$		
White	1.1	0.6; 1.9	0.4	0.2; 0.8	0.6	0.3; 0.9	1.7	1.3; 2.2	0.041
Brown	5.1[c]	2.7; 8.5	1.0	0.2; 4.1	0.7	0.0; 2.6	1.9	0.9; 3.5	0.001
Black			1.4	0.5; 4.4	0.9	0.4; 1.9	1.2	0.5; 2.4	
Family income (quintiles)[b]	$P = 0.001^b$		$P = 0.047^b$		$P = 0.008^b$		*P*		
Q1 (poorest)	4.6	2.2; 8.2	2.0	0.8; 4.8	1.6	0.8; 2.7	2.1	1.1; 3.4	0.076
Q2	3.0	1.4; 5.6	0.2	0.0; 0.9	0.7	0.2; 1.5	1.5	0.7; 2.6	0.249
Q3	1.6	0.5; 3.7	0.4	0.0; 1.3	0.5	0.1; 1.3	1.5	0.7; 2.6	0.986
Q4	0.7	0.0; 2.3	0.0	–	0.3	0.0; 0.9	1.7	0.9; 2.8	0.026
Q5 (richest)	0.0	–	0.0	–	0.3	0.0; 0.9	1.2	0.6; 2.4	0.010
All children	1.8	1.2; 2.6	0.6	0.3; 1.1	0.6	0.4; 0.9	1.7	1.3; 2.1	<0.001

[a]p-value are displayed from inter-cohorts chi squared test.

[b]p-value are displayed from intra-cohort chi-squared test.

[c]Black and brown were combined.

CI, Confidence interval.

Table 4. Prevalence of underweight (Z score <2 SD for weight-for-age) at age 12 months according sex, maternal skin colour and family income in the 1982, 1993, 2004 and 2015 cohorts

	1982		1993		2004		2015		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	P^a
Sex	$P = 0.700^b$		$P = 0.070^b$		$P = 0.200^b$		$P = 0.360^b$		
Males	4.1	2.7; 5.8	2.6	1.7; 4.0	2.5	1.9; 3.3	1.7	1.2; 2.4	<0.001
Females	3.6	2.4; 5.3	1.4	0.9; 2.4	1.9	1.3; 2.6	1.3	0.9; 2.0	<0.001
Maternal skin colour	$P < 0.001^b$		$P = 0.014^b$				$P = 0.918^b$		
White	2.9	2.0; 3.9	1.5	0.9; 2.3	1.8	1.4; 2.4	1.6	1.2; 2.1	0.001
Brown	8.6[c]	5.4; 12.7	2.0	0.7; 5.5	1.9	0.6; 4.3	1.6	0.7; 3.0	<0.001
Black			4.5	2.6; 7.8	3.8	2.5; 5.4	1.3	0.6; 2.6	
Family income (quintiles)[b]	$P < 0.001^b$		$P < 0.001^b$		$P < 0.001^b$		$P = 0.058^b$		
Q1 (poorest)	10.5	6.7; 15.3	5.3	3.2; 8.6	4.5	3.2; 6.2	2.7	1.7; 4.2	<0.001
Q2	5.3	3.0; 8.4	1.8	0.8; 4.0	2.9	1.8; 4.3	1.3	0.6; 2.4	<0.001
Q3	3.8	2.0; 6.5	1.3	0.7; 2.5	1.7	0.9; 2.9	1.2	0.5; 2.3	0.001
Q4	1.3	0.4; 3.0	1.0	0.4; 1.9	0.9	0.3; 1.8	1.2	0.6; 2.2	0.440
Q5 (richest)	0.3	0.0; 1.8	0.0	0.0; 0.9	1.2	0.5; 2.2	1.2	0.5; 2.4	0.102
All children	3.9	2.9; 5.0	2.1	1.5; 2.8	2.2	1.8; 2.7	1.5	3.3; 4.6	<0.001

[a] *P*-values are displayed from intercohorts chi square test.
[b] *P*-values are displayed from intracohort chi square test.
[c] Black and brown colours were combined.

Table 5. Prevalence of overweight (>2 Z scores of weight-for-length) at age 12 months according sex, maternal skin colour and family income in the 1982, 1993, 2004 and 2015 cohorts

	1982		1993		2004		2015		
	%	95% CI	%	95% CI	%	95% CI	%	95% CI	P^a
Sex	$P = 0.005^b$		$P = 0.100^b$		$P = 0.400^b$		$P = 0.016^b$		
Males	8.3	6.4; 10.6	10.7	8.5; 13.7	8.6	7.4; 12.0	13.5	12.0; 15.0	<0.001
Females	4.7	3.3; 6.5	8.1	6.0; 10.6	7.8	6.7; 9.1	10.9	9.5; 12.3	<0.001
Maternal skin colour	$P = 0.865^b$		$P = 0.144^b$		$P = 0.099^b$		$P = 0.742^b$		
White	6.6	5.2; 8.1	10.0	8.2; 12.2	8.8	7.8; 9.9	12.0	10.8; 13.3	<0.001
Brown	6.3[c]	3.6; 10.0	1.9	2.6; 13.1	5.9	3.4; 9.4	11.9	9.2; 15.0	<0.001
Black			8.7	5.4; 13.9	7.0	5.3; 9.1	13.1	10.5; 16.1	
Family income (quintiles)[b]	$P = 0.021^b$		$P = 0.804^b$		$P = 0.446^b$		$P = 0.353^b$		
Q1 (poorest)	4.6	2.2; 8.2	9.2	5.9; 14.0	8.4	6.5; 10.6	12.4	10.1; 15.0	<0.001
Q2	6.6	4.1; 10.0	8.0	5.3; 12.1	7.5	5.8; 9.6	10.8	8.7; 13.3	0.027
Q3	3.5	1.8; 6.1	8.9	5.6; 13.8	7.4	5.6; 9.5	13.9	11.5; 16.6	<0.001
Q4	7.8	5.1; 11.4	11.6	7.8; 16.8	9.7	7.8; 12.0	12.5	10.3; 14.9	0.018
Q5 (richest)	9.5	6.5; 13.4	9.4	6.1; 14.3	8.1	6.2; 10.3	12.2	9.8; 15.0	0.148
All children	6.5	5.3; 7.9	9.4	7.8; 11.3	8.2	7.4; 9.2	12.2	11.2; 13.2	<0.001

[a] *P*-values are displayed from intercohorts chi square test.
[b] *P*-values are displayed from intracohort chi square test.
[c] Black and brown colours were combined.

Discussion

Our results describe how the nutrition transition affected children born in a Brazilian city over a period of more than three decades. Stunting prevalence fell by 53%, from 8.3% in 1982 to 3.9% in 2015, whereas overweight prevalence increased by 88%, from 6.5% to 12.2%. As described in the Introduction, both undernutrition and overweight in early life are important risk factors for a number of conditions along the life course. Our results do not indicate a specific period of time or decade when these changes took place (Figure 1). Taking into account the confidence intervals of the estimates, our results are consistent with steady declines in stunting and underweight, a steady increase in overweight and low, stable levels of wasting. Also, our results do not suggest that the children in Pelotas are facing a double burden of malnutrition, as overweight has replaced stunting, rather than co-existing with stunting, at population level.

The relatively low prevalence of stunting in 1982—less than 10%—must be interpreted in light of the fact that stunting is a cumulative, long-term process that reaches the highest prevalences after 24 months of age.[23] For example, in the same 1982 cohort, prevalence of stunting was 12.2% at 2 years of age, reaching 25.1% in the poorest group of children.[24] Globally, it is estimated that approximately 24% of all children under the age of 5 are stunted, and in Latin America the prevalence in this age group was 9.5% in 2016.[9]

Stunting prevalence is declining in many countries.[7,9] The reasons behind the decline in stunting in Brazil include improvements in socioeconomic determinants of health, including increased maternal education and poverty reduction, improved coverage with essential services including water supply and sanitation, and universal access to health care.[25] As shown in previous articles in the present Supplement, time trends in determinants of stunting in Pelotas were consistent with national trends.[14,19,26] In Pelotas as in Brazil as a whole, there were marked reductions in socioeconomic inequalities in stunting, which likely reflect an improvement in living conditions for Brazil's poor families.[11]

Wasting prevalence remained below 2% in the four cohorts. Low prevalence levels have been observed for many decades in most of Latin America,[27] where regional prevalence is estimated at 1.3%.[9] In Pelotas there was an apparent increase in 2015, when prevalence reached 1.7% compared with 0.6% in 1993 and 2004 (Table 3). The reasons behind this increase are unclear. In terms of inequalities, prevalence fell by more than 50% over time for the poorest children and among those born to mothers with black or brown skin colour, whereas children born to white-skinned and upper socioeconomic status mothers presented stable prevalence.

Other articles in this series describe time trends in factors that may have contributed to improved nutrition, including increased income and maternal schooling[14]—particularly for the poor,[14] fewer teenage pregnancies and lower fertility,[11] a reduction in maternal undernutrition,[27] improved health care during pregnancy[28] and increased breastfeeding duration,[29] all of which took place in the city during the time period covered by the cohorts.

When interpreting time trends in stunting and wasting, it is important to note that the statistically based prevalence of below -2 Z scores indicates that—even in a population with optimal nutritional conditions—the expected prevalence would be 2.3%.[30] Both for stunting and wasting, levels in the richest quintile in Pelotas had already been close to this minimum value in 1982, and as a consequence the overall reductions in undernutrition depended solely on improvements among the poor. In 1982, disparities in stunting and wasting presented what is known as a 'bottom inequality' pattern, with substantially higher prevalence among the poorest children compared with all other groups.[31] By 2015, prevalence in the poorest quintile was still higher than for the remaining quintiles, but the differences amounted to a couple of percentage points or less.

In light of Brazil's success in reducing undernutrition, the main nutritional challenge presented by its children is that of overweight. Childhood body mass index (BMI)—particularly at the age of 2 years or later—tends to track over the life course, with well-described consequences regarding the risk of non-communicable diseases.[3,32] Our report of a prevalence of 12.2% among 12-month-old children in 2015 is higher than that of 7.4% estimated for Latin American under-five children.[9] Although analyses of 5–19-year-olds in Brazil suggested an important increase in overweight prevalence,[6] paralleling the increase observed among adults,[33] so far there have been no reports of an epidemic among young children. We report an increase of 88% between 1982 and 2015, with a particularly fast upsurge after 2004; data from national surveys up to 2007 failed to detect such a recent increase.[33] Causes for the obesity epidemic among Brazilian adults are complex and involve poor diets— and in particular the consumption of highly calorific industrialized foods— as well as reductions in physical activity.[34] Further studies are required to understand what is driving the obesity epidemic among children. In view of the inverse association between breastfeeding and child obesity,[29,35] it will be important to understand the rise in overweight during a period of time when breastfeeding rates have shown substantial increase.[36]

Inequalities in overweight prevalence were reduced. Whereas prevalence was directly associated with family income in 1982, the increase over time was equal to 63% in the poorest and 22% in the richest quintile, thus effectively eliminating inequalities by 2015. Our findings constitute a perverse example where a reduction in inequalities was due to the worsening of nutritional status among the poor.

The official Brazilian classification for ethnicity relies on self-assessed skin colour, a classification that is widely accepted and promoted by Afro-Brazilians, who advocate for disaggregation of government statistics in order to reveal inequities.[19] Children born to women with black or brown skin colour showed 40% greater risk of stunting when the four cohorts were pooled, with no evidence of a reduction in this ratio over time. In 1982, there were also important ethnic gaps in wasting, but these were no longer present in 2015. Further research is needed to understand why the ethnic gap was reduced for stunting but not for wasting. In contrast, there was no evidence of ethnic differences in overweight prevalence in any of the cohorts. In Brazilian society, ethnicity and socioeconomic status are strongly associated, and this is also the case for Pelotas.[14] National-level analyses confirm the lower risk of several morbidity and mortality indicators for white-skinned women and their children, compared with those with brown or black skin colour.[37]

Boys had higher prevalence than girls, ranging from 20% to 40% excess, in the three anthropometric indicators studied. It is well-known that the male sex has greater biological frailty in childhood, presenting higher mortality and morbidity rates, and an analysis of 81 countries had previously shown a 14% increase in the risk of stunting among boys than girls.[1,38]

Our analyses have some limitations. Information on family income was reported by women in the perinatal interview, and may be affected by random error and possibly by systematic error as well, with over-reporting of income by the poor and under-reporting by the rich. In particular, hyperinflation was occurring in Brazil in 1993, and obtaining accurate information on income was problematic. Nevertheless, the clear patterns observed for stunting—which is strongly influenced by socioeconomic conditions[1]—are reassuring. The follow-up rate in the 12-month visit to the 1982 cohort, of 79.1%, was well below those for the other three cohorts, of 93% or higher. This raised the possibility of bias. We investigated this possibility by comparing the prevalence of low birthweight among children who were measured at 12 months (which was 6.8%) and those who were lost to follow-up (7.9%). Follow-up rates showed little variation according to family income (75.6% in the poorest and 82.5% in the highest family income groups), and there were no differences according to sex or skin colour.[39] These findings suggest that follow-up bias was not important.

Unlike the three more recent cohorts, the visit at 1 year of age to the 1982 cohort was restricted to children born in the first 4 months of the year. The second follow-up to the 1982 cohort (around 2 years of age) included all children born in that year, so that it is possible to compare the prevalence of undernutrition by calendar months of birth.[17] In this follow-up, the prevalences of stunting, wasting and overweight were 13.3% (95% CI 11.6; 14.9), 0.7% (0.3; 1.1) and 5.4% (4.3; 6.5) for children born January-April, and 14.3% (13.1; 15.5), 0.8% (0.5; 1.1) and 7.7% (6.8; 8.6) for those born May-December. Therefore, there is no evidence of bias for underweight and wasting, and for overweight the prevalence was 2.3% points higher for children born later in the year. Given that the prevalence of overweight in the 2015 cohort was 12.2% (Table 5), even if the results for 1982 were biased downwards, the increase over time is still evident.

The strengths of the studies include their population-based, prospective design, the use of comparable methodology by the same research team over time and—except for 1993—the high rates of follow-up. It should also be noted that Pelotas was one of the six sites providing data for the 2006 World Health Organization Growth Standards,[18] which were used for assessing nutritional status in the present analyses.

Summing up, our comparison of the four cohorts showed marked improvements in undernutrition over a 33-year period, with concomitant reductions in socioeconomic and, to a lesser extent, in ethnic inequalities. Overweight prevalence, on the other hand, increased markedly, particularly among the poor. The nutrition transition is bringing new challenges to public health in Brazil.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Center, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centers of Excellence (PRONEX), Brazilian National Council for Scientific and Technological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Alicia Matijasevich,[1] Andrea Dãmaso Bertoldi,[2] Diego G Bassani,[3] Fernando C Wehrmeister,[2] Iná S Santos,[2] Joseph Murray,[2] Luciana Tovo-Rodrigues,[2] Maria Cecilia F Assunção,[2] Mariangela F Silveira[2] and Pedro R C Hallal.[2]

[1]University of São Paulo, Brazil, [2]Federal University of Pelotas, Brazil and [3]University of Toronto, Canada.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i26–i36
doi: 10.1093/ije/dyy278
Supplement Article

Supplement Article

Maternal anthropometry: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Bernardo L Horta ,[1] Fernando C Barros,[2] Natália P Lima,[1] Maria C F Assunção,[1] Iná S Santos,[1] Marlos R Domingues ,[1] Cesar G Victora [1]* and the Pelotas Cohorts Study Group**

[1]Postgraduate Program in Epidemiology, Federal University of Pelotas and [2]Postgraduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

*Corresponding author. Postgraduate Program in Epidemiology, Federal University of Pelotas, Rua Marechal Deodoro, 1160, 3 andar, 96020-220, Pelotas, RS, Brazil. E-mail: cvictora@gmail.com
**Members listed at end of article.

Editorial decision 14 November 2018; Accepted 24 November 2018

Abstract

Background: Pre-pregnancy nutritional status and weight gain during pregnancy have short- and long-term consequences for the health of women and children. This study was aimed at evaluating maternal height,- and overweight or obesity at the beginning of the pregnancy and gestational weight gain, according to socioeconomic status and maternal skin colour of mothers in Pelotas, a southern Brazilian city, in 1982, 1993, 2004 and 2015.

Methods: In 1982, 1993, 2004 and 2015, the maternity hospitals in Pelotas were visited daily, all deliveries were identified and mothers who lived in the urban area of the city were interviewed. Maternal weight at the beginning of the pregnancy was self-reported by the mother or obtained from the antenatal card. Maternal height was collected from the maternity records or measured by the research team. Overweight or obesity was defined by a body mass index $\geq$25 kg/m^2. Gestational weight gain was evaluated according to the Institute of Medicine guidelines.

Results: In the four cohorts, we evaluated 19 931 women. From 1982 to 2015, the prevalence of overweight or obesity at the beginning of the pregnancy increased from 22.1% to 47.0% and height increased by an average of 5.2 cm, whereas gestational weight gain did not change. Socioeconomic status was positively associated with maternal height, and the difference between the poorest and the wealthiest decreased. Overweight or obesity was lower among those mothers in the extreme categories of family income.

Conclusions: Over the 33-year span, mothers were taller at the beginning of the pregnancy, but the prevalence of overweight or obesity more than doubled.

Key words: Nutritional status, anthropometry, maternal health, pregnancy, socioeconomic factors, cohort studies

Key Messages

- Maternal height increased byan average of 5.2 cm from 1982 to 2015 and inequalities by socioeconomic status decreased.
- Increase in weight was greater than that observed for height, and prevalence of overweight or obesity at the beginning of the pregnancy increased from 22.1% to 47.0%
- Prevalence of maternal underweight at the beginning of the pregnancy decreased, but the reduction was higher among the wealthiest mothers and inequalities by socioeconomic status increased.

Introduction

Maternal nutritional status during pregnancy is often evaluated through anthropometric indicators such as pre-pregnancy height, weight and body mass index (BMI), and by weight gain during pregnancy. Maternal height results from the interaction of the genetic potential for growth with early life conditions,[1] whereas maternal pre-pregnancy weight and BMI reflect nutritional status before conception. Gestational weight gain, on the other hand, depends on health and nutrition during pregnancy.

Malnutrition before and during pregnancy may have short- and long-term consequences. Maternal height, weight, BMI and gestational weight gain are positively associated with intrauterine growth and birthweight.[2] Maternal height is also associated with long-term consequences, being positively related to the offspring's human capital[3] and linear growth.[4] Maternal underweight is a risk factor for several perinatal outcomes.[5] On the other hand, pre-pregnancy overweight or obesity increases the risk of stillbirth and infant mortality,[6] preterm birth and large-for-gestational- age babies.[7] Excessive weight gain during pregnancy is a risk factor for adverse fetal and maternal outcomes.[8] Furthermore, maternal obesity and higher gestational weight gain possibly increase the risk of obesity and of non-communicable diseases in the offspring.[9]

Globally, adult height and BMI[10,11] have been steadily increasing both for men and women, and obesity has reached epidemic proportions.[11] In an earlier report comparing the Pelotas (Brazil) birth cohorts of 1982 and 2004, mean maternal height increased from 156.4 cm to 158.8 cm, and in all cohorts maternal height was positively associated with family income; the same period witnessed a marked increase in pre-pregnancy BMI. Maternal BMI was lower among the mothers in the extreme categories of family income, i.e. the poorest and wealthiest.[12,13]

In the present study, we report on: maternal height; preconceptional underweight, overweight and obesity; and gestational weight gain, according to socioeconomic position and maternal skin colour in the four population-based birth cohorts that were studied in the city of Pelotas (southern Brazil) in 1982, 1993, 2004 and 2015. We hypothesized that the trends observed from 1982 to 2004, particularly the increase in stature and in overweight and obesity,[12] would continue to evolve in the period from 2004 to 2015. We focus on the description of time trends in levels and inequalities, rather than on the identification of other risk factors for anthropometric status.

Methods

In 1982, 1993, 2004 and 2015, all maternity hospitals in Pelotas were visited daily and all children born to women who lived in the urban area of the city were examined, and their mothers were interviewed using a pre-coded questionnaire, soon after the delivery.[14] Fewer than 1% of all births in the city took place outside a hospital, and subjects have been followed on several occasions; further details on the methodology of each birth cohort have been published elsewhere.[15–18]

In the four cohorts, information on maternal weight at the beginning of the pregnancy was obtained from the antenatal card, or through self-report if the information was not available on the card. Regarding maternal weight at the end of the pregnancy, in 1982 and 1993 women were weighed at hospital admission wearing light clothes and without shoes, using a scale (Filizola, precision 100 g) that was calibrated weekly by the research team using standard weights, and this information was abstracted by the research team from the maternity records. In 2004 and 2015, the mothers were asked about their weight at the end of the pregnancy during the perinatal interview. Concerning maternal height, in 1982 and 1993 mothers were measured at hospital admission by hospital staff and the research team retrieved this information from maternity records, whereas in 2004 and 2015 the mothers were measured at home, during the 3 months' follow-up visit. In the four cohorts, all height measurements were carried out with the same model of a locally made portable stadiometer, with 1 mm precision.

Pre-pregnancy body mass index (in kg/m^2) was calculated using the information on height and maternal weight at the beginning of the pregnancy. Overweight was defined by a body mass index at the beginning of the pregnancy $\geq$25 and <30 kg/m^2, obesity by a BMI $\geq$30 kg/m^2, overweight or obesity by a BMI >25 $kg/m^2$and underweight by a BMI <18.5 kg/m^2. Gestational weight gain was evaluated according to the Institute of Medicine (IOM) guidelines, which recommend weight gain ranges of 12.5–18.0 kg, 11.5–16.0 kg, 7–11.5 kg and 5.0–9.0 kg, among underweight, normal weight, overweight and obese mothers, respectively. For multiple pregnancies, we used the provisional IOM guidelines.[19]

The units of analyses were women who gave birth to a live-born child or to a stillbirth (a fetus with a gestational age of 28 or more weeks, or a birthweight of 1000 g or higher when gestational age was not known). Measurement procedures of birthweight and gestational age have been reported elsewhere.[20] Single and multiple pregnancies were included.

Analyses were stratified by family income quintiles and maternal skin colour (white, brown or black). Further information on the stratification variables is available elsewhere.[14] With respect to skin colour, in 1982 the interviewer classified maternal skin colour as white, black or other (either indigenous or yellow/Asian), and mothers with brown skin colour were classified as black. In 1993, the interviewer also classified the colour, and an option for brown skin color was included. In 2004 and 2015, skin colour was self-reported by the mothers using the five categories (white, brown, black, indigenous, yellow/Asian) employed by the Brazilian census bureau. Means and proportions were compared using analysis of variance (ANOVA) and chi square testing, respectively. Tests for heterogeneity and linear trends were carried out, and we reported the one with the lowest *P*-value of the two results. We compared differences inter- and intra-cohorts, i.e. in the inter-cohort comparisons we compared the change in the estimate across cohorts, for each category of the explanatory variable. For intra-cohort analysis, we estimated the likelihood that differences among the categories of the exposure variable were due to chance.

Two summary indices were used to assess the magnitude of income-related disparities.[21] The slope index of inequality is a measure of absolute inequality and shows the difference in the outcome, expressed as percentage points, between the extremes of the wealth scale. The concentration index is a measure similar to the Gini coefficient, and reflects relative inequalities. Both indices range from −100 to +100, with positive values showing that the outcome is more common in the high-income group than in the poorest group. Both indices are based on the full distribution of the outcomes in the five wealth quintiles.[21] A weighted least-square regression was used to carry out a formal statistical test of the variation in the concentration index and the slope index of inequality across the cohorts. Data analyses were carried out using Stata software 15.[22]

Ethical approval for observational studies was not required in Brazil until 1996.The 2004 study was approved by the Ethics Committee of the School of Medicine and the 2015 study by the Ethics Committee of the School of Physical Education, Federal University of Pelotas, and written informed consent was obtained from the mothers.

Results

Response rates during the perinatal interview were greater than 98% in all four cohorts.[14] From 1982 to 2015, the number of total births, including stillbirths, fell from 6011 to 4329. Additional information on the sociodemographic characteristics of the mothers in the four cohorts are presented elsewhere.[14]

Table 1 shows that average maternal height increased by 5.2 cm, from 156.4 cm in 1982 to 161.6 cm in 2015. The increment was slightly higher between 1982 and 1993 than from 2004 to 2015, whereas from 1993 to 2004 there was a slight decrease in height. Mean pre-pregnancy weight increased by 11.5 kg from 1982 to 2015, with the largest increment taking place between 2004 and 2015. Because the increase in weight was faster than that in height, a sharp increase in BMI was observed, mostly in the latest 11-year period. Whereas the prevalence of underweight declined from 7.8% to 3.7%, there was a marked increase in the prevalence of pre-pregnancy overweight or obesity, which affected about half of all women in 2015. Although mean gestational weight gain varied across the cohorts, there was no clear time trend and the means for 1982 and 2015 were similar. However, the proportion of mothers who gained more weight than recommended by the IOM guidelines was higher in 2004 and 2015, because a greater proportion of women were overweight or obese at the start of pregnancy—and therefore should have gained less weight.

Table 2 shows mean maternal height in each cohort, disaggregated by quintiles of family income and maternal skin colour. In all four cohorts, maternal height was

Table 1. Maternal height, pre-pregnancy body mass index and weight gain during pregnancy in four birth cohorts, Pelotas, Brazil

	Birth cohort (year)[a]				*P*-value
	1982	1993	2004	2015	
Maternal height (cm)[b]	156.4 (156.3; 156.6) 5902	159.8 (159.6; 160.0) 5256	158.8 (158.5; 159.0) 4011	161.6 (161.3; 161.8) 4204	<0.01
Maternal height <150 cm (%)[c]	16.0 (15.1; 16.9)	8.6 (7.9; 9.4)	8.9 (8.1; 9.8)	6.1 (5.4; 6.9)	<0.01
Pre-pregnancy weight (kg)[b]	55.7 (55.5; 56.0) 5146	58.2 (57.9; 58.5) 5190	61.0 (60.6; 61.4) 3998	67.2 (66.7; 67.6) 4267	<0.01
Pre-pregnancy body mass index (kg/m^2)[b]	22.7 (22.6; 22.8) 5055	22.8 (22.7; 22.9) 5147	23.6 (23.4; 23.7) 3775	25.7 (25.5; 25.8) 4152	<0.01
Pre-pregnancy underweight (BMI <18.5 kg/m^2) (%)[c]	7.8 (7.0; 8.5)	8.8 (8.1; 9.6)	7.4 (6.5; 8.5)	3.7 (3.2; 4.3)	<0.01
Pre-pregnancy overweight (BMI ≥25 and < 30 kg/m^2) (%)[c]	17.7 (16.7; 18.8)	17.5 (16.5; 18.6)	20.4 (19.0; 21.9)	28.2 (26.9; 29.6)	<0.01
Pre-pregnancy obesity (BMI ≥ 30 kg/m^2) (%)[c]	4.4 (3.9; 5.0)	4.9 (4.3; 5.5)	9.0 (8.0; 10.0)	18.7 (17.6; 20.0)	<0.01
Pre-pregnancy overweight or obesity (BMI ≥25 kg/m^2) (%)[c]	22.1 (21.0; 23.3)	22.4 (21.2; 23.6)	29.4 (27.7; 31.0)	47.0 (45.5; 48.5)	<0.01
Gestational weight gain (kg)[b]	11.8 (11.7; 12.0) 4468	11.6 (11.5; 11.8) 5067	12.4 (12.2; 12.6) 3949	12.0 (11.8; 12.2) 4230	<0.01
Gestational weight gain according to IOM guidelines					<0.01
Below the recommendation (%)	41.0 (39.5; 42.4)	42.6 (41.2; 44.0)	27.5 (26.1; 28.9)	30.8 (29.4; 32.2)	
Within the recommendation (%)	34.4 (33.1; 35.9)	33.8 (32.5; 35.1)	32.4 (31.0; 33.9)	33.5 (32.1; 34.9)	
Above the recommendation (%)	24.6 (23.3; 25.9)	23.6 (22.5; 24.8)	40.1 (38.6; 41.6)	35.7 (34.3; 37.2)	

[a]95% confidence interval is presented between brackets.
[b]Mean.
[c]Prevalence.

positively associated with family income. Mean height increased markedly over time in all socioeconomic groups, but the increase was greater in the two poorest quintiles (5.9 and 7.1 cm, respectively) than in the two richest quintiles (3.9 and 4.4 cm, respectively). The slope index of inequality and the concentration index suggest that the gap between the wealthiest and the poorest narrowed ($P < 0.01$), mostly from 1982 to 1993. Regarding maternal skin colour, in 1993 and 2004 no differences in mean height were observed between white, brown and black women, and the increase in height over time was comparable in all three groups. On the other hand, in 1982 white mothers were taller than non-white mothers ($P = 0.02$), whereas in 2015 the 95% confidence intervals show that maternal height was higher among black and white mothers than for women with brown skin colour ($P < 0.01$).

Maternal underweight prevalence is presented in Table 3. Except for 1982, there were inverse associations with family income. Important reductions over time were observed in all income groups, particularly among women in the richest quintiles. As a consequence, inequalities tended to increase slightly, particularly in relative terms as measured by the concentration index ($P = 0.02$). Regarding skin colour, we did not observe major differences across the cohorts.

In all four cohorts, the prevalence of pre-pregnancy overweight or obesity showed inverted U-shaped patterns according to income, with the highest prevalence in the intermediate quintiles (Table 4). Prevalence more than doubled between 1982 and 2015 in all but the second quintile. The slope and concentration indices do not show evidence of income-related inequality in maternal overweight or obesity in any cohort, as all confidence intervals included the

Table 2. Maternal height according to family income and skin colour in four birth cohorts, Pelotas, Brazil

	Mean maternal height in cm (95% confidence interval)				*P*-value
	1982	1993	2004	2015	
Quintiles of family income					
P -value	<0.01[a]	<0.01[b]	<0.01[b]	<0.01[b]	
Q1 (poorest)	154.1	158.1	157.5	160.0	<0.01[c]
	(153.8; 154.4)	(157.7; 158.5)	(157.0; 157.9)	(159.6; 160.5)	
Q2	153.7	159.2	157.7	160.8	<0.01[c]
	(153.4; 154.0)	(158.8; 159.6)	(157.3; 158.2)	(160.3; 161.2)	
Q3	157.2	159.5	158.5	161.2	<0.01[c]
	(157.0; 157.5)	(159.1; 160.0)	(158.1; 158.9)	(160.8; 161.6)	
Q4	158.0	160.6	159.0	161.9	<0.01[c]
	(157.7; 158.4)	(160.2; 161.0)	(158.6; 159.5)	(161.5; 162.3)	
Q5(wealthiest)	159.4	161.7	160.7	163.8	<0.01[c]
	(159.0; 159.7)	(161.3; 162.1)	(160.3; 161.1)	(163.4; 164.2)	
Concentration index	0.75 (0.69; 0.80)	0.40 (0.33; 0.46)	0.38 (0.31; 0.45)	0.44 (0.36; 0.51)	<0.01
Slope index of inequality	1.60 (1.49; 1.71)	0.76 (0.64; 0.88)	0.76 (0.63; 0.90)	0.76 (0.64; 0.88)	<0.01
Maternal skin colour					
P-value	0.0[a]	0.09[a]	0.30[a]	<0.01[a]	
White	156.5	159.8	158.7	161.9	<0.01[c]
	(156.4; 156.7)	(159.6; 160.0)	(158.5; 159.0)	(161.6; 162.1)	
Brown		158.9	158.2	159.9	<0.01[c]
	156.0[d]	(158.0; 159.8)	(157.5; 159.0)	(159.4; 160.5)	
Black	(155.7; 156.4)	160.0	158.5	161.5	<0.01[c]
		(159.6; 160.4)	(158.0; 158.9)	(160.9; 162.1)	

[a]*P*-value for heterogeneity from intra-cohort ANOVA tests.
[b]*P*-value for linear trend from intra-cohort ANOVA tests.
[c]*P*-value for heterogeneity from inter-cohort ANOVA tests.
[d]In 1982, brown women were classified as black; the results presented here expressed the mean height of black and brown women.

reference (0). For maternal skin colour, the prevalence was lowest among white women in each cohort, but prevalence increased to similar extents in all groups over time. Table 5 shows that over the 33-year span, the prevalence of obesity increased by at least four times in all but the second quintile. Supplementary Figure 1 (available as Supplementary data at *IJE* online) shows that the prevalence of obesity presented an inverted U-shaped pattern with family income. We also analysed the trends for overweight (Supplementary Table 1, available as Supplementary data at *IJE* online).

In all cohorts except for 2015, the proportion of mothers whose weight gain was above the recommended range (Table 6) was higher in the top income quintile, but the fastest increase was observed in the poorest quintiles. Accordingly, the concentration and slope indices show important declines in inequalities over time ($P < 0.01$). From 1982 to 2004 weight gain was not associated with skin colour, but in 2015 the proportion of mothers with a weight gain above the recommendation was lower among white women compared with other women.

Discussion

The strengths of our analyses include the population-based nature of the samples. Each perinatal study included nearly all births in a calendar year and response rates were above 98%, thus minimizing the likelihood of selection bias. The four studies were conducted by the same group of researchers. The study's limitations included differences in the assessment of maternal weight. Whereas in 1982 and 1993 women were weighed at hospital admission, in 2004 and 2015 the information on the weight at the end of the pregnancy was provided by the mothers, who usually reported their weight at the latest antenatal care visit. This change in the way of assessing maternal weight may have biased our analysis of the trend of gestational weight gain. Moreira and colleagues studied the agreement between self-reported and measured weights in the 2013 national health survey in Brazil, showing that there was a high degree of agreement between both variables.[23] Headen *et al.*[24] systematically reviewed the evidence on the accuracy of self-reported

Table 3. Prevalence of maternal underweight at the beginning of the pregnancy according to family income and skin colour in four birth cohorts, Pelotas, Brazil

	Prevalence of maternal underweight (95% confidence interval)				*P*-value
	1982	1993	2004	2015	
Quintiles of family income					
***P*-value**	0.13[a]	<0.01[a]	<0.01[a]	<0.01[a]	
Q1 (poorest)	8.8 (7.1; 10.9)	9.9 (8.2; 11.9)	9.8 (7.6; 12.7)	5.8 (4.4; 7.6)	<0.01[b]
Q2	7.0 (5.6; 8.8)	10.6 (8.9; 12.5)	9.9 (7.7; 12.8)	3.9 (2.8; 5.4)	<0.01[b]
Q3	9.0 (7.4; 10.9)	9.1 (7.4; 11.2)	7.4 (5.5; 9.9)	3.7 (2.6; 5.2)	<0.01[b]
Q4	7.6 (6.1; 9.3)	7.4 (5.9; 9.2)	6.3 (4.6; 8.5)	2.4 (1.5; 3.6)	<0.01[c]
Q5(wealthiest)	6.5 (5.1; 8.1)	6.4 (5.1; 8.1)	4.6 (3.2; 6.5)	3.0 (2.1; 4.4)	<0.01[c]
Concentration index	−4.53 (−9.87; 0.80)	−7.81 (−12.77; −2.85)	−15.25 (−22.29; −8.21)	−13.27 (−22.36; −4.18)	0.02
Slope index of inequality	−2.03 (−4.55; 0.49)	−4.27 (−6.96; −1.58)	−7.04 (−10.38; −3.70)	−3.40 (−5.54; −1.27)	0.41
Maternal skin colour					
P-value	0.44[a]	0.20[a]	0.20[a]	0.63[a]	
White	7.9 (7.1; 8.7)	8.9 (8.1; 9.8)	7.4 (6.4; 8.6)	3.6 (3.0; 4.3)	<0.01[c]
Brown	7.1[d]	11.6 (8.0; 16.4)	10.2 (6.8; 15.2)	4.4 (3.0; 6.5)	<0.01[c]
Black	(5.5; 9.0)	7.8 (6.3; 9.8)	6.4 (4.6; 8.8)	3.9 (2.6; 5.7)	<0.01[c]

[a]*P*-value for heterogeneity from intra-cohort chi square tests.
[b]*P*-value for heterogeneity from inter-cohort chi square tests.
[c]*P*-value for linear trend from inter-cohort chi square tests.
[d]In 1982, brown women were classified as black; the results presented here expressed the prevalence of underweight among black and brown women.

maternal weight across pregnancy. Concerning weight at the end of pregnancy, most studies reported errors of small magnitude, with mothers tending to under-report their weight. Because the last antenatal care visit usually takes place before the day of delivery, in 2004 and 2015 we did not capture the change in weight between the antenatal care visit and the delivery, and thus weight gain during pregnancy was underestimated. Since this error is expected to be independent of socioeconomic status, non-differential misclassification bias may be present. This will tend to underestimate the associations with risk factors in 2004 and 2015. Other limitations, regarding the collection of information on family income and skin colour, are further discussed in the first article in this supplement.[14] The misclassification of family income that may have occurred in 1993, due to the hyperinflation, tends to be unrelated to maternal nutritional status and this error may have underestimated the association of nutritional status with socioeconomic status in 1993. By the same token, the change in the assessment of skin colour (as the 'brown' category was not considered in 1982) may have introduced some noise in the observed associations.

In the 33-year period covered by the four birth cohorts, there were important changes in sociodemographic characteristics of the mothers, which are described in an accompanying article.[14] There were important improvements in education and income. The proportion of adolescent mothers remained stable, but there was a substantial increase in the number of mothers aged 35 years or older. Parity declined rapidly, and birth intervals increased.

The present results show that average maternal height and pre-pregnancy weight increased markedly. Because the increase was faster for weight than for height, the prevalence of pre-pregnancy overweight or obesity rose from 22.1% in 1982 to 47.0% in 2015. The fastest increase took place after 2004. On the other hand, weight gain during pregnancy did not change across the cohorts, but this could be at least partly due to the above-mentioned differences in how the final weight was assessed in 2004 and 2015.

Table 4. Prevalence of overweight or obesity at the beginning of the pregnancy according to family income and skin colour in four birth cohorts, Pelotas, Brazil

	Prevalence of overweight or obesity at the beginning of the pregnancy (95% confidence interval)				*P*-value
	1982	1993	2004	2015	
Quintiles of family income					
P-value	<0.01[a]	0.07[a]	<0.01[a]	<0.01[a]	
Q1 (poorest)	18.6 (16.2; 21.3)	21.2 (18.7; 23.8)	22.8 (19.5; 26.6)	41.8 (38.4; 45.2)	<0.01[c]
Q2	28.2 (25.5; 31.1)	22.1 (19.9; 24.6)	31.3 (27.5; 35.3)	50.1 (46.6; 53.5)	<0.01[b]
Q3	21.7 (19.3; 24.2)	24.5 (21.8; 27.5)	30.6 (27.0; 34.6)	52.4 (49.0; 55.8)	<0.01[c]
Q4	23.2 (20.8; 25.8)	24.4 (21.8; 27.2)	33.7 (30.1; 37.5)	50.7 (47.3; 54.0)	<0.01[c]
Q5(wealthiest)	18.7 (16.4; 21.1)	20.0 (17.7; 22.6)	27.8 (24.5; 31.3)	39.8 (36.6; 43.2)	<0.01[c]
Concentration index	−2.52 (−5.42; 0.39)	0.02 (−2.71; 3.08)	3.12 (0.00; 6.30)	−0.71 (−2.56; 1.14)	0.44
Slope index of inequality	−3.00 (−6.81; 0.88)	0.11 (−3.76; 3.98)	5.08 (−0.50; 10.65)	−1.92 (−7.13; 3.29)	0.33
Maternal skin colour					
P-value	<0.01[a]	0.03[a]	0.08[a]	<0.01[a]	
White	20.9 (19.7; 22.1)	21.7 (20.4; 23.0)	28.2 (26.4; 30.2)	45.9 (44.2; 47.7)	<0.01[c]
Brown	28.5[d]	22.2 (17.3; 28.1)	31.7 (25.7; 38.4)	46.0 (41.8; 50.2)	<0.01[c]
Black	(25.5; 31.6)	25.7 (23.0; 28.6)	32.8 (29.0; 36.9)	53.1 (49.2; 57.0)	<0.01[c]

[a]*P*-value for heterogeneity from intra-cohort chi square tests.
[b]*P*-value for heterogeneity from inter-cohort chi square tests.
[c]*P*-value for linear trend from inter-cohort chi square tests.
[d]In 1982, brown women were classified as black; the results presented here expressed the prevalence of overweight or obesity among black and brown women.

Both small stature and underweight were more common among low-income women. Inequalities in maternal heights according to income fell rapidly particularly between 1982 to 1993 but, in contrast, inequalities in underweight increased slightly due to faster reductions in the richest quintiles where the prevalence is rather low. In contrast, overweight or obesity did not show a linear association with income, and inequalities in overweight or obesity were small and remained stable during the study period, as prevalence increased in all quintiles. Weight gains during pregnancy above the recommendations were more frequent among high-income women in 1982, but by 2015 these differences were markedly reduced due to faster increase among the poor. Generally speaking, women from all income groups were more similar in terms of anthropometric status in 2015 than they were in 1982. On the one hand this is a positive finding, as is the case for height, but on the other hand improved equality was due to the faster rises among the poor in overweight or obesity and weight gain during pregnancy above the recommendation. When equity improves as a function of worsening status among the poor, the improvement is illusory.

The findings on maternal anthropometry are consistent with the reduction in stunting and the increase in overweight or obesity in the children from the four cohorts, which are described in another article in this supplement.[25] Changes in inequalities were also similar for mothers and children: the socioeconomic gap in stunting was greatly reduced, but the faster increase in overweight or obesity among poor children led to the elimination of the gap that was present in 1982.

The findings from our four cohorts are consistent with the global increase in overweight and obesity, which has reached epidemic levels in several countries.[11] Increases in the prevalence of overweight and obesity in the beginning of pregnancy have been described in high-income countries,[26–28] where several studies report higher prevalence of obesity among mothers of low socioeconomic status.[28,29]

Table 5. Prevalence of obesity at the beginning of the pregnancy according to family income and skin colour in four birth cohorts, Pelotas, Brazil

	Prevalence of obesity at the beginning of the pregnancy (95% confidence interval)				*P*-value
	1982	1993	2004	2015	
Quintiles of family income					
P-value	<0.01[a]	0.10[a]	0.51[a]	<0.01[a]	
Q1 (poorest)	3.6	4.0	8.1	17.8	<0.01[c]
	(2.5; 5.0)	(3.0; 5.5)	(6.1; 10.8)	(15.3; 20.5)	
Q2	6.7	5.1	10.1	20.3	<0.01[b]
	(5.3; 8.4)	(3.9; 6.5)	(7.9; 13.0)	(17.7; 23.2)	
Q3	4.8	5.7	9.9	21.3	<0.01[c]
	(3.7; 6.3)	(4.4; 7.5)	(7.7; 12.6)	(18.6; 24.1)	
Q4	4.5	5.9	9.1	20.8	<0.01[c]
	(3.4; 5.9)	(4.6; 7.5)	(7.1; 11.7)	(18.2; 23.7)	
Q5(wealthiest)	2.5	3.7	7.7	13.6	<0.01[c]
	(1.7; 3.7)	(2.7; 5.1)	(5.9; 10.0)	(11.4; 16.0)	
Concentration index	−8.6 (−15.20; −2.02)	0.12 (−6.49; 6.73)	−1.31 (−7.83; 5.22)	−3.70 (−7.20; −0.21)	0.55
Slope index of inequality	−2.37 (−4.18; -0.58)	−0.02 (−1.92; 1.88)	−1.19 (−4.66; 2.27)	−3.93 (−7.84; −0.01)	0.96
Maternal skin colour					
P-value	<0.01[a]	0.14[a]	0.01[a]	0.22[a]	
White	3.9	4.5	8.1	18.2	<0.01[c]
	(3.4; 4.6)	(3.9; 5.2)	(7.0; 9.3)	(16.8; 19.6)	
Brown		5.8	13.2	19.3	<0.01[c]
	7.0[d]	(3.3; 9.7)	(9.2; 18.5)	(16.2; 22.8)	
Black	(5.4; 8.9)	6.0	10.8	21.1	<0.01[c]
		(4.7; 7.7)	(8.4; 13.7)	(18.1; 24.5)	

[a]*P*-value for heterogeneity from intra-cohort chi square tests.
[b]*P*-value for heterogeneity from inter-cohort chi square tests.
[c]*P*-value for linear trend from inter-cohort chi square tests.
[d]In 1982, brown women were classified as black; the results presented here expressed the prevalence of obesity among black and brown women.

In contrast, studies from low-income countries show higher prevalence among wealthy women, although this pattern is changing rapidly.[30] A study of national trends in Brazil up to 2008[31] showed that the prevalence of obesity was increasing faster among the poor than among the rich women. In contrast, we found that although the absolute increase in percentage points was greater for poor than for rich women (Supplementary Figure 1), there were similar 5-fold increases in prevalence in both the poorest and richest quintiles. Both the national study and our own findings show that the prevalence of obesity was highest among women in the intermediate categories of socioeconomic status. This pattern of association did not change over time. On the other hand, similarly to other settings, black mothers were more likely to be overweight.[28,29]

As observed in other countries, we documented an important increase in maternal height over time. This increase in height in our birth cohorts was more pronounced in two different periods, from 1982 to 1993 and from 2004 to 2015. Over the 33-year span, mean maternal height increased by about 5 cm and the proportion of mothers whose height was <150 cm decreased from 16.0% in 1982 to 6.0% in 2015. Though an increase in adult height has been reported worldwide,[10] an analysis of data from 54 low- to middle-income countries showed that in 35 of them a stagnation or decline in female height has been documented in most recent birth cohorts,[32] with the increase in height being concentrated among women in the wealthiest socioeconomic groups in more recent years.

In Pelotas, the slope index of inequality and the concentration index make clear that the difference in maternal height between the richest and the poorest narrowed, mostly from 1982 to 1993, which indicates that socioeconomic inequalities in terms of maternal height decreased. The improvements in maternal height which we documented in our cohorts have also been observed for height of young children; Gonçalves *et al.* reported a marked

Table 6. Prevalence of weight gain during pregnancy above the recommended range, according to family income and skin colour in four Birth Cohorts. Pelotas, Brazil

	Percentage weight gain during pregnancy above the recommendations (95% confidence interval)				*P*-value
	1982	1993	2004	2015	
Quintiles of family income					
P-value	<0.01[b]	<0.01[a]	<0.01[b]	<0.01[a]	
Q1 (poorest)	15.7 (13.2; 18.6)	21.9 (19.4; 24.6)	33.5 (30.2; 37.0)	30.1 (27.1; 33.4)	<0.01[c]
Q2	21.1 (18.5; 24.0)	20.8 (18.5; 23.2)	38.9 (35.5; 42.3)	39.4 (36.2; 42.8)	<0.01[c]
Q3	24.4 (21.8; 27.3)	22.8 (20.1; 25.7)	40.9 (37.5; 44.4)	36.5 (33.4; 39.8)	<0.01[c]
Q4	25.6 (22.9; 28.4)	24.6 (22.1; 27.4)	43.3 (39.9; 46.7)	36.1 (32.9; 39.4)	<0.01[c]
Q5(wealthiest)	33.3 (30.4; 36.3)	28.6 (25.9; 31.4)	43.4 (40.0; 46.8)	36.3 (33.2; 39.6)	<0.01[c]
Concentration index	13.22 (10.31; 16.12)	5.70 (2.83; 8.57)	4.72 (2.53; 6.91)	1.82 (−0.50; 4.13)	<0.01
Slope index of inequality	18.92 (14.63; 23.21)	7.75 (3.68; 11.83)	11.60 (6.38; 16.83)	4.24 (−0.71; 9.18)	<0.01
Maternal skin colour					
P-value	0.51[a]	0.18[a]	0.26[b]	0.04[b]	
White	24.8 (23.4; 26.2)	24.1 (22.8; 25.5)	40.6 (38.8; 42.4)	34.8 (33.1; 36.5)	<0.01[c]
Brown	23.6[e]	19.4 (14.7; 25.3)	39.2 (33.6; 45.1)	37.8 (33.8; 41.9)	<0.01[c]
Black	(20.6; 26.9)	22.4 (19.8; 25.2)	38.4 (35.0; 41.9)	38.6 (34.9; 42.4)	<0.01[d]

[a]*P*-value for heterogeneity from intra-cohort chi square tests.
[b]*P*-value for linear trend from intra-cohort chi square tests.
[c]*P*-value for heterogeneity from inter-cohort chi square tests.
[d]*P*-value for linear trend from inter-cohort chi square tests.
[e]In 1982, brown women were classified as black; the results presented here expressed the mean weight gain during pregnancy of black and brown women.

decrease in the prevalence of stunting at 12 months of age,[25] as well as reductions in socioeconomic inequalities. In Brazil, the prevalence of stunting in childhood decreased from 37.1% in 1974–75 to 7.1% in 2006–7.[33] Because undernutrition in childhood is positively associated with stature in adulthood,[3] such improvement in maternal height was expected and should be associated with further improvements in the next generation, as early growth is associated with intrauterine growth in the next generation.[34]

This analysis showed positive trends in maternal height and socioeconomic inequality which increased and declined, respectively. On the other hand, the increase in maternal overweight or obesity is a cause for concern, given its short- and long-term consequences on the health of the mother and the baby. These findings reinforce the need for ample public health policies aimed at tackling the obesity epidemic.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Center, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centers of Excellence (PRONEX), Brazilian National Council for Scientific and Tehcnological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Aluisio J D Barros,[1] Alicia Matijasevich,[2] Ana M B Menezes,[1] Andrea Dâmaso Bertoldi,[1] Diego G Bassani,[3] Fernando C

Wehrmeister,[1] Helen Gonçalves,[1] Joseph Murray,[1] Luciana Tovo-Rodrigues,[1] Mariangela F Silveira[1] and Pedro R C Hallal.[1]

[1]Federal University of Pelotas, Brazil, [2]University of São Paulo, Brazil and [3]University of Toronto, Canada.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i16–i25
doi: 10.1093/ije/dyy169
Supplement Article

Supplement Article

Maternal reproductive history: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Alicia Matijasevich,[1,2]* Cesar G Victora,[2] Mariangela F Silveira,[2] Fernando C Wehrmeister,[2] Bernardo L Horta,[2] Fernando C Barros[2,3] and the Pelotas Cohorts Study Group**

[1]Department of Preventive Medicine, Faculty of Medicine FMUSP, University of São Paulo, São Paulo, Brazil, [2]Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil and [3]Postgraduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

*Corresponding author. Department of Preventive Medicine, Faculty of Medicine FMUSP, University of São Paulo, Av. Dr. Arnaldo 455, 2nd floor, room 2166, CEP 01246-903, SP, Brazil. E-mail: alicia.matijasevich@fm.usp.br
**Members listed at end of article.

Editorial decision 5 July 2018; Accepted 20 July 2018

Abstract

Background: Brazil experienced important progress in maternal and child health in recent decades. We aimed at describing secular trends as well as socioeconomic and ethnic inequalities in reproductive history indicators (birth spacing, previous adverse perinatal outcome, parity and multiple births) over a 33-year span.

Methods: Four population-based birth cohort studies included all hospital births in 1982, 1993, 2004 and 2015 in Pelotas, Southern Brazil. Information on reproductive history was collected through interviews. Indicators were stratified by family income quintiles and skin colour. Absolute and relative measures of inequality were calculated.

Results: From 1982 to 2015, the proportion of primiparae increased from 39.2% to 49.6%, and median birth interval increased by 23.2 months. Poor women were more likely to report short intervals and higher parity, although reductions were observed in all income and ethnic groups. History of previous low birthweight was inversely related to income and increased by 7.7% points (pp) over time—more rapidly in the richest (12.1 pp) than in the poorest quintile (0.4 pp). Multiple births increased from 1.7% to 2.7%, with the highest increase observed among the richest quintile and for white women (220% and 70% increase, respectively). Absolute and relative income and ethnic-related inequalities for short birth intervals increased, whereas inequalities for previous low birthweight decreased over time.

Conclusions: In this 33-year period there were increases in birth intervals, multiple births and reports of previous low-birthweight infants. These trends may be explained by increased family planning coverage, assisted reproduction and a rise in preterm births, respectively. Our results show that socioeconomic and ethnic inequalities in health are dynamic and vary over time, within the same location.

Key words: Reproductive health, health equity, socioeconomic factors, cohort studies

Key Messages

- Along with an important decrease in fertility rates, median birth interval increased by 23 months and the proportion of primiparae increased from 39% in 1982 to nearly 50% in 2015.
- Although the frequency of short birth intervals (<36 months) was reduced over the period, women belonging to low-income groups still showed the highest values.
- Reports of previous preterm births increased over time and almost doubled among the poorest women, whereas reports of previous low-birthweight births increased mainly among the wealthiest.
- There was a steady increase in the incidence of multiple births in Pelotas, reaching higher levels than those reported for Brazil as a whole; the increase was restricted to high-income and to white women.
- Relative inequalities for short birth intervals, at least one previous pregnancy and multiple births increased, whereas those for low birthweight decreased over the study period.

Introduction

Caring for and investing in womeńs and childreńs health are vital components of the right to health, encompassing reproductive, maternal, newborn and child health care.[1] Maternal reproductive history, a known predictor of maternal health and pregnancy outcomes, should always be investigated during antenatal care, given its importance for guiding medical and therapeutic procedures. The most important indicators include birth spacing, previous adverse perinatal outcomes, parity and multiple births.

Birth spacing may be assessed through the time interval between delivery and conception of the next pregnancy (inter-pregnancy interval) or birth of the next child (birth interval), both of which substantially affect perinatal mortality, gestational age and birthweight, as well as the risk of pregnancy complications for mothers.[2–5] Both short and long intervals, variously defined, have been associated with adverse outcomes, and a number of causal mechanisms were postulated,[2] but the literature suggests that a single cut-off point of 36 months is adequate for predicting maternal and infant outcomes.[6,7]

The history of adverse perinatal events in a previous gestation increases the risk of developing an adverse outcome in subsequent pregnancies. History of a previous abortion, stillbirth, low birthweight and/or preterm birth are some of the best-documented indicators of adverse perinatal events. A recent systematic review showed almost a 4-fold increase of a new fetal death among women with a history of a previous stillbirth, compared with women with no such history.[8] Subsequent pregnancies after a stillbirth or abortion—either spontaneous or induced—have been associated with increased risks of preterm and low birthweight births.[9,10]

The associations with parity vary according to the obstetric and neonatal outcomes under study. Compared with women with one to three previous births, the incidence of postpartum haemorrhage, preeclampsia, placenta praevia, macrosomia, post-date pregnancy and low Apgar scores is higher for grand multiparae (i.e. women having had four or more previous births).[11] In contrast, neonatal and perinatal mortality are higher among babies born to nulliparous (i.e. women having no previous births) as well as to grand multiparous women, compared with those born to women with one to three previous deliveries.[12]

Multiple births are increasingly frequent, especially in high-income countries.[13] These are associated with a number of complications both for the mother and fetus. Mothers suffer substantial morbidity due to the increased incidence in medical complications, and fetuses carry substantially higher risks of premature delivery, perinatal mortality and long-term neurodevelopmental impairments.[14]

In Brazil, maternal and child health outcomes are affected by the profound socioeconomic and ethnic group inequalities that characterize our society.[15–17] For women, such inequalities affect their own health status—before, during and after pregnancy—directly and by limiting their access to and use of health services,[18] and may be propagated in a transgenerational cycle.[19] Research in such inequalities is needed, not only due to their effect in individual populations, but also because they are costly and burdensome to the entire health care system of a country.[20]

Brazil is the largest country in South America and the fifth largest country in the world.[21] Its demographic transition began in the mid-1950s, since when there was an accelerated decline in population growth rates as a consequence of a steady reduction in fertility, from 6.1 children per woman in 1960 to 1.7 in 2015.[22] The transition occurred concomitantly with cultural transformations, an intense process of industrialization, an increase of per capita income and education levels and a steady decline in infant mortality. Since the 1980s, Brazil also underwent positive changes in the social determinants of health and a universal health care system was created, with major improvements in maternal and child health indicators and in access to health care. Yet, important health inequalities still persist in the country.[17]

The city of Pelotas in southern Brazil is located in a relatively developed area of the country. It is a medium-sized city with around 340 000 inhabitants and a highly inequitable income distribution.[23] During the years of 1982, 1993, 2004 and 2015, cohort studies including all births in the city were started, providing the opportunity to investigate how maternal reproductive history indicators (i.e. birth spacing, previous adverse perinatal outcome, parity and multiple births) evolved over time. The present study was aimed at describing secular trends for all women giving birth in the city, as well as for specific socioeconomic and ethnic groups, over a 33-year span.

Methods

All women delivering in one of the Pelotas hospitals during the years of 1982, 1993, 2004 and 2015, and who were resident in the urban area of the city, were invited to participate in a population-based birth cohort study. Whereas in the 1982 and 1993 cohorts, infants who were less than 28 weeks of gestational age or weighed below 1000 g were excluded, in the two most recent cohort studies only newborns younger than 20 weeks or weighing below 500 g were excluded. Similar methodology was employed in all studies,[24–27] including consistent variable definitions and comparable questions. The city's maternity wards were visited on a daily basis, and mothers were interviewed at the hospital soon after delivery. Home births represented less than 1% of all births. Variables included in the present study were collected during the perinatal interview for the four cohorts.

Birth interval was defined as the number of months between the dates of the birth of the cohort child and the immediately preceding birth to the mother. Calculation was restricted to women with at least one previous live birth. Short birth intervals were defined as less than 36 months. Parity was defined as the number of times that a woman had given birth to a live-born baby (with any sign of life, irrespective of gestational age) or to a stillbirth (28 weeks of pregnancy or more), prior to the index pregnancy.

Women with at least one previous pregnancy were asked about abortions (induced or spontaneous), stillbirths and live births. If the pregnancy ended with a stillbirth or a live birth, it was enquired whether the outcome of the pregnancy was a preterm and/or low birthweight birth. Preterm birth was defined as a delivery before 37 completed gestational weeks, and low birthweight as less than 2500 g at birth. Information about previous preterm births was not available in the 1982 Pelotas cohort study.

In 1982 and 1993, maternal skin colour was classified according to the interviewer's observation, and in 2004 and 2015 was based on self-report. In 1982, only two categories were used, white or brown/black, whereas in the subsequent cohorts, three groups (as black, brown or white) were coded, according to the classification adopted by the Brazilian Census Bureau.[28]

Family income during the month preceding delivery of the index child was used as a measure of socioeconomic position. Family income was collected in Brazilian real and quintiles were calculated within each cohort. We refer to the first quintile (Q1) as the poorest quintile/poorest 20% and the fifth quintile (Q5) as the wealthiest quintile/wealthiest 20%.

Socioeconomic and ethnic inequalities in maternal reproductive history indicators (birth spacing, previous adverse perinatal outcome, parity and multiple births) were studied. In the present article we refer to inequalities as any measurable aspect of health that varies across individuals or groups, differentiating this term from inequities, which are systematic differences that are unfair and unjust.[29]

In order to investigate whether the effect of socioeconomic position on the outcomes varied over time, interactions between socioeconomic indicators (family income and maternal skin colour) and cohort year, fitted as an ordinal variable starting with 1982, for each of the reproductive outcomes were tested through logistic regression. Two indicators of economic-related inequality were estimated: (i) an indicator of absolute inequality, the slope index of inequality; and (ii) an indicator of relative inequality, the concentration index.[30]

The slope index of inequality is derived via regression of mean health outcome within a particular social group on the mean relative rank of social groups.[31,32] In the case of quintiles of family income, each quintile included approximately 20% of the cohort, and midpoints of the quintile categories were calculated. The slope index of inequality was then obtained by regressing the outcomes studied on the midpoint score for each category. The slope of the regression line represents the absolute difference between the highest (score 1) and the lowest (score of 0) values of the socioeconomic position indicator.

The concentration index was calculated in its relative formulation, with no corrections.[33] The concentration index uses an analogous approach to the Gini index, by ranking individuals according to socioeconomic position on the x-axis and for cumulative health condition on the y-axis. This index is expressed on a scale ranging from −100 to 100; a value of 0 represents perfect equality. If the outcome is more concentrated toward the richer groups, the concentration index assumes a positive value, as the curve is below the diagonal. When poorer groups are more affected than richer groups, the concentration index is negative.[33,34]

Ethnic group inequalities were studied using relative [i.e. ratio of (black plus brown) vs white] and absolute comparisons [i.e. the arithmetical difference between (black + brown) and white].

Data analyses included chi-square tests for heterogeneity and linear trends. As the intervals among the four cohorts are equal (11 years each), we used the x^2 test for trend to compare the distribution of categorical outcome variables between cohort studies. This test was also used to analyse trends in reproductive outcomes within each category of family income and maternal skin colour over time. All analyses were performed with Stata V.14.0.[35]

Ethical approval for studies was not required in Brazil until 1996. The 2004 study was approved by the Ethics Committee of the School of Medicine and the 2015 by the School of Physical Education, Federal University of Pelotas, and written consent was obtained from the mothers.

Results

Totals of 6011, 5304, 4287 and 4329 births were enrolled in the 1982, 1993, 2004 and 2015 birth cohort studies, respectively. The number of births decreased by 28% over the 33-year study period. Non-response rates at recruitment were below 2% in all cohorts.

Births occurring among primiparae, that is firstborn children, increased by 25% (from 39.2% in 1982 to 49.6% in 2015). As a consequence, the proportion of women with a previous reproductive history—having had at least one previous pregnancy—decreased by 17% (from 60.7% in 1982 to 50.4% in 2015) (Table 1).

The largest decline in reporting at least one previous pregnancy was observed among the richest women (32% reduction) and absolute and relative inequalities increased over time (Table 2). Black and brown women were more likely to report at least one previous pregnancy than white women in each cohort; however, inequalities remained stable over time (Table 3).

Table 1. Time trends in reproductive history variables, Pelotas birth cohort studies

Variables	1982 n (%)	1993 n (%)	2004 n (%)	2015 n (%)	P-value
Parity					<0.001*
Primiparae	2357 (39.2)	1860 (35.1)	1684 (39.3)	2145 (49.6)	
1	1685 (28.0)	1471 (27.7)	1118 (26.1)	1330 (30.7)	
≥2	1967 (32.7)	1973 (37.2)	1484 (34.6)	852 (19.7)	
Median birth interval (months)[a]	35.0	48.3	55.0	58.2	<0.001*
Short birth interval (<36 months)[a]					<0.001
No	1736 (49.2)	1972 (63.8)	1647 (69.2)	1009 (70.6)	
Yes	1790 (50.8)	1118 (36.2)	733 (30.8)	421 (29.4)	
Previous preterm[a]					<0.001
No	NA	3060 (89.1)	1927 (80.2)	1756 (81.4)	
Yes		373 (10.9)	476 (19.8)	400 (18.6)	
Previous low birthweight[a]					<0.001
No	2767 (81.7)	2919 (85.3)	1932 (80.6)	1615 (75.2)	
Yes	620 (18.3)	503 (14.7)	465 (19.4)	533 (24.8)	
Multiple births					<0.001
No	5909 (98.3)	5223 (98.5)	4201 (98.0)	4213 (97.3)	
Yes	102 (1.7)	81 (1.5)	86 (2.0)	116 (2.7)	
Previous stillbirth[a]					0.410
No	3497 (95.8)	3349 (97.2)	2494 (95.8)	2108 (96.6)	
Yes	154 (4.2)	95 (2.8)	108 (4.2)	74 (3.4)	
Previous abortion[a]					0.067
No	2798 (76.7)	2474 (71.8)	1873 (72.0)	1752 (80.3)	
Yes	851 (23.3)	970 (28.2)	729 (28.0)	430 (19.7)	
Total of births	6011	5304	4287	4329	

NA, not available.

[a]Among women with at least one previous pregnancy.

P-value: x^2 test for linear trend; *P-value: x^2 test for heterogeneity.

Table 2. Maternal reproductive history variables per cohort and family income quintile

Cohort study	Prevalence and CI 95%, per family income quintile					Slope index of inequality (95% CI)	Concentration Index (95% CI)
	Poorest	2nd	3rd	4th	Richest		
At least one previous pregnancy							
1982	63.8 (61.0; 66.5)	67.9 (65.2; 70.5)	57.1 (54.2; 60.0)	56.9 (54.0; 59.7)	58.0 (55.1; 60.8)	−11.1 (−15.4; -6.9)	−3.3 (−4.4; -2.1)
1993	70.0 (67.1; 72.8)	67.1 (64.4; 70.0)	63.9 (60.7; 67.0)	62.6 (59.6; 65.6)	60.2 (57.1; 63.2)	−11.2 (−15.6; -6.8)	−2.9 (−4.1; -1.8)
2004	62.6 (59.3; 65.8)	66.5 (63.3; 69.6)	61.7 (58.3; 65.1)	60.4 (57.0; 63.7)	52.0 (48.6; 55.5)	−13.1 (−18.2; -8.0)	−3.5 (−4.9; -2.1)
2015	56.4 (53.0; 59.7)	57.3 (54.0; 60.7)	52.8 (49.4; 56.2)	45.8 (42.5; 49.2)	39.7 (36.4; 43.0)	−21.7 (−26.7; -16.7)	−7.2 (−8.9; -5.5)
x^2 test for linear trend	P <0.001	P <0.001	P = 0.097	P <0.001	P <0.001		
Median birth interval (months)[a]							
1982	14.0	34.0	36.0	40.0	37.0	8.8 (4.8; 12.8)	0.03 (0.02; 0.1)
1993	29.0	45.8	52.2	52.9	57.1	23.7 (18.5; 28.8)	0.06 (0.04; 0.07)
2004	43.0	47.9	55.9	63.7	69.0	31.8 (25.3; 38.4)	0.08 (0.06; 0.09)
2015	47.4	49.8	67.4	72.2	58.7	25.3 (15.9; 34.7)	0.06 (0.04; 0.08)
x^2 test	P <0.001	P <0.001	P <0.001	P <0.001	P <0.001		
Short birth interval[a]							
1982	59.9 (56.2; 63.5)	52.0 (48.4; 55.5)	47.8 (44.0; 51.7)	44.6 (40.7; 48.5)	48.5 (44.7; 52.3)	−15.2 (−20.8; -9.5)	−4.8 (−6.7; -2.9)
1993	46.4 (42.6; 50.3)	39.1 (35.6; 42.8)	33.2 (29.2; 37.4)	32.0 (28.2; 36.1)	25.7 (22.0; 29.6)	−21.9 (−27.6; -16.1)	−10.0 (−12.7; -7.3)
2004	41.8 (37.5; 46.2)	34.8 (30.8; 39.0)	30.1 (26.0; 34.4)	23.3 (19.6; 27.4)	20.3 (16.4; 24.7)	−26.3 (−32.4; -20.1)	−13.8 (−17.2; -10.4)
2015	38.5 (33.2; 44.0)	33.0 (28.0; 38.4)	27.1 (22.1; 32.5)	19.3 (14.6; 24.9)	25.1 (19.7; 31.2)	−20.7 (−28.8; -12.6)	−11.4 (−16.0; -6.7)
x^2 test for linear trend	P <0.001	P <0.001	P <0.001	P <0.001	P <0.001		
Previous preterm[a]							
1982	NA	NA	NA	NA	NA	–	–
1993	11.0 (8.8; 13.5)	11.9 (9.7; 14.3)	11.0 (8.6; 13.9)	10.6 (8.3; 13.2)	9.1 (6.9; 11.6)	−1.8 (−5.4; 1.7)	−2.5 (−7.9; 3.0)
2004	23.2 (19.6; 27.1)	20.3 (17.0; 23.9)	19.6 (16.1; 23.4)	20.4 (16.8; 24.3)	14.1 (10.7; 17.9)	−8.2 (−13.7; -2.7)	−5.4 (−10.0; -0.8)
2015	19.7 (16.2; 23.5)	21.9 (18.3; 25.8)	18.1 (14.6-22.0)	17.9 (14.3; 22.1)	13.5 (10.0; 17.6)	−7.3 (−12.9; -1.8)	−6.1 (−11.1; -1.1)
x^2 test for linear trend	P <0.001	P <0.001	P = 0.001	P <0.001	P = 0.021		
Previous low birthweight[a]							
1982	28.6 (25.2; 32.1)	23.8 (20.8; 27.0)	14.9 (12.3; 17.9)	13.3 (10.7; 16.1)	10.0 (7.9; 12.6)	−23.5 (−28.0; -19.0)	−20.8 (−24.7; -16.8)
1993	18.1 (15.3; 21.1)	18.0 (15.4; 20.8)	14.5 (11.7; 17.7)	12.9 (10.4; 15.8)	8.1 (6.1; 10.5)	−11.2 (−15.3; -7.2)	−12.2 (−16.7; -7.7)
2004	24.8 (21.1; 28.7)	22.4 (19.0; 26.2)	18.1 (14.7; 21.9)	17.6 (14.3; 21.4)	11.7 (8.9; 15.3)	−14.6 (−20.0; -9.2)	−10.8 (−15.4; -6.2)
2015	29.0 (25.0; 33.3)	22.8 (19.1; 26.7)	23.5 (19.6; 27.7)	26.2 (21.9; 30.8)	22.1 (17.8-26.9)	−5.2 (−11.6; 1.2)	−4.4 (−8.6; -0.1)
x^2 test for linear trend	P = 0.480	P = 0.984	P <0.001	P <0.001	P <0.001		
Multiple births							
1982	2.1 (1.4; 3.1)	1.0 (0.5; 1.7)	1.2 (0.6; 2.0)	2.1 (1.4; 3.1)	2.1 (1.4; 3.1)	0.5 (−0.7; 1.7)	5.7 (−6.7; 18.2)
1993	1.2 (0.7; 2.1)	1.2 (0.7; 2.0)	1.8 (1.0; 2.9)	1.6 (0.9; 2.5)	1.9 (1.1; 2.9)	0.8 (−0.4; 1.9)	8.8 (−3.6; 21.3)
2004	2.9 (1.9; 4.3)	1.6 (0.9; 2.7)	1.9 (1.1; 3.1)	1.4 (0.7; 2.4)	2.2 (1.3; 3.4)	−0.9 (−2.5; 0.7)	0.1 (−12.2; 12.5)
2015	1.8 (1.1; 3.0)	3.0 (2.0; 4.4)	2.1 (1.2; 3.3)	1.8 (1.1; 3.0)	4.6 (3.3; 6.3)	2.2 (0.4; 4.0)	10.2 (−0.8; 21.1)
x^2 test for linear trend	P = 0.712	P <0.001	P = 0.105	P = 0.559	P = 0.001		

[a]Among women with at least one previous pregnancy.
P-value = x^2 test for linear trend for reproductive outcomes within each category of family income over time.

Table 3. Maternal reproductive history variables per cohort and maternal skin colour

Cohort study	Prevalence and CI 95%, per maternal skin colour			Absolute inequality (PP) (brown + black) -white	Relative inequality (brown + black)/white
	White	Brown	Black		
At least one previous pregnancy					
1982	59.6 (58.3; 61.0)	66.0 (63.0; 68.8)		6.4	1.1
1993	63.6 (62.1; 65.1)	66.7 (60.3; 72.6)	70.3 (67.3; 73.1)	6.0	1.1
2004	58.1 (56.4; 59.9)	68.6 (63.0; 73.8)	67.3 (64.1; 70.4)	9.5	1.2
2015	49.1 (47.4; 50.9)	52.9 (48.7; 57.1)	54.5 (50.6; 58.3)	4.7	1.1
x^2 test for linear trend	P <0.001	P <0.001	P <0.001		
Median birth interval (months)[a]					
1982	35.0	30.0		−5.0	0.9
1993	51.4	41.8	37.5	−13.3	0.8
2004	56.7	53.8	48.9	−6.6	0.9
2015	63.1	48.8	47.4	−15.3	0.8
x^2 test	P <0.001	P = 0.110	P = 0.001		
Short birth interval[a]					
1982	48.9 (47.0; 50.7)	58.8 (55.0; 62.5)		9.9	1.2
1993	33.1 (31.2; 35.0)	40.1 (32.0; 48.7)	47.0 (43.0; 51.0)	12.6	1.4
2004	28.2 (26.1; 30.5)	32.6 (26.0; 40.0)	37.8 (33.7; 42.0)	8.2	1.3
2015	25.9 (23.2; 28.7)	38.9 (32.1; 46.1)	37.2 (30.9; 43.8)	12.1	1.5
x^2 test for linear trend	P <0.001	P = 0.936	P = 0.001		
Previous preterm[a]					
1982	NA	NA	NA		
1993	10.5 (9.3; 11.7)	13.3 (8.4; 19.6)	11.8 (9.5; 14.5)	1.6	1.2
2004	18.5 (16.6; 20.4)	24.2 (18.4; 30.9)	22.3 (18.9; 26.0)	4.3	1.2
2015	17.7 (15.8; 19.8)	22.1 (17.6; 27.3)	19.1 (15.1; 23.6)	2.8	1.2
x^2 test for linear trend	P <0.001	P = 0.053	P <0.001		
Previous low birthweight[a]					
1982	17.2 (15.8; 18.6)	23.2 (20.0; 26.7)		6.0	1.3
1993	13.9 (12.6; 15.3)	17.1 (11.6; 23.9)	17.1 (14.3; 20.1)	3.2	1.2
2004	18.0 (16.2; 20.0)	21.1 (15.6; 27.6)	23.0 (19.5; 26.7)	4.5	1.3
2015	24.2 (22.0; 26.4)	16.2 (12.2; 20.9)	34.8 (29.8; 40.0)	2.0	1.1
x^2 test for linear trend	P <0.001	P = 0.627	P <0.001		
Multiple births					
1982	1.7 (1.3; 2.1)	1.9 (1.1; 2.8)		0.2	1.1
1993	1.5 (1.2; 1.9)	0.4 (0.01; 2.3)	1.9 (1.1; 2.9)	0.1	1.1
2004	1.9 (1.5; 2.5)	2.0 (0.7; 4.3)	2.3 (1.4; 3.5)	0.3	1.2
2015	2.8 (2.3; 3.5)	2.5 (1.4; 4.1)	2.1 (1.2; 3.5)	−0.5	0.8
x^2 test for linear trend	P <0.001	P = 0.065	P = 0.652		

[a]Among women with at least one previous pregnancy.
P-value = x^2 test for linear trend for reproductive outcomes within each category of maternal skin colour over time.

Even though the overall prevalence of short birth intervals decreased by half over time (Table 1), the poorest women and those with black or brown skin were more likely to report short birth intervals than the richest and white women in each cohort (Tables 2 and 3). Short birth interval prevalence declined faster among the latter groups, leading to an increase in absolute and relative inequalities over time.

History of a previous preterm birth increased by 70% between 1993 and 2015 (Table 1), being negatively associated with income in the 2004 and 2015 cohorts (Table 2). Whereas among poor women, reports of previous preterm births almost doubled, the increase among the wealthiest women was equal to 50%. The increase was also faster among black and brown women than among whites (Table 3). Income inequalities were small and increased discreetly over time, and ethnic inequalities remained almost stable (Tables 2 and 3).

History of a previous low birthweight birth showed a 35% increase in the whole population over the study period (Table 1), being inversely related to income in all cohorts (Table 2). Contrary to stable levels among brown women, there were increases of 40% among white and 200% among black women from 1993 to 2015 when information on the three skin colour groups was collected (Table 3). Also, levels were stable over time for the two poorest quintiles, but increased by 58%, 96% and 220% for those belonging to the 3th, 4th and 5th income quintile, respectively, in the period 1982–2015. Both absolute and relative inequalities decreased in the study period (Tables 2 and 3).

Multiple births showed a 60% increase between 1982 and 2015 (Table 1), mainly due to a 220% increase in the wealthiest women (Table 2). Absolute and relative economic inequalities also increased over time, with the highest inequalities observed in 2015, when multiple births were twice as common among the richest than among the poorest (Table 2). White women showed a 64% increase in multiple births, but no such trends were observed among black or brown women (Table 3). The magnitude of absolute and relative inequalities by ethnicity was low and remained stable over time.

History of previous stillbirth and abortion remained stable at approximately 4% and 25%, respectively (Table 1). Supplementary Tables 1 and 2, available as Supplementary data at *IJE* online, show that there were no time trends in income-related inequalities for these two outcomes. Reports of previous abortions were reduced over time for white women while remaining stable among black women, thus leading to increased absolute and relative ethnic inequalities (Supplementary Table 2, available as Supplementary data at *IJE* online).

Interactions between socioeconomic indicators (family income and maternal skin colour) and cohort year are described in Supplementary Table 3, available as Supplementary data at *IJE* online. Given the multiplicative nature of logistic regression, interaction tests refer to relative inequalities and are consistent with concentration index results. The presence of an interaction indicates that relative inequality changed over time, this being the case for birth intervals, at least one previous pregnancy and multiple births, where relative inequalities increased, and for previous low birthweight, where these decreased. The lack of evidence of an interaction between income and cohort year for previous stillbirths, previous preterm births and previous abortions is also in agreement with the lack of changes in relative inequalities over time. No interaction was observed between maternal skin colour and cohort year for most of maternal reproductive history outcomes, indicating that inequalities did not change over time.

Discussion

During the study period, total yearly number of births dropped by 1800 and the median birth interval increased by 23.2 months. Low-income women were more likely to report short birth intervals and higher parity, but reductions over time were observed for all income and ethnic groups. Previous preterm births increased over time and almost doubled among the poorest women, whereas previous low birthweight births increased mainly among the wealthiest but to similar extent in all ethnic groups. The overall prevalence of multiple births increased, especially in the richest quintile and for white women. Absolute and relative income- and ethnic-related inequalities for short birth intervals increased, whereas inequalities for previous low birthweight decreased over time.

In the past three decades, Brazil experienced major political and economic changes that had a profound impact on the living conditions of its population. The country experienced economic growth up to 2011, and several social protection programmes targeting the poorest population groups were implemented. Coverage of essential maternal health interventions such as use of modern contraceptives, attendance at antenatal care and institutional delivery increased and equity improved dramatically, with the poorest 20% showing the fastest rates of improvement. Prevalence of modern contraceptive use increased from 57% in 1986 to 83% in 2013, and the family planning needs satisfied indicator—which excludes women who are willing to get pregnant—reached almost universal coverage.[36]

In spite of economic improvement in the country as a whole, the Pelotas region had slower growth than the rest of the country, as documented elsewhere.[23] In 1982, the per capita gross domestic product of the city was similar to the national level, but dropped to 74% of the national value by 2015.[23] Nevertheless, substantial improvements in maternal health and education were observed in the city during the course of the study period.[37]

Changes in reproductive histories over time reflected the sharp decline in fertility observed for Brazil as a whole.[17] The crude birth rate for Pelotas fell from 23.1 to 12.9 births per 1000 population, and the annual number of births dropped in the same period in spite of population increase.[23] Along with such a major decline in fertility, the proportion of primiparae increased from 39% to nearly 50% and the median birth interval increased by 0.7 months per calendar year. The decline in fertility is consistent with that observed for Brazil as a whole, where projected values indicate a total fertility rate of 1.69 children per woman for 2016.[38] This process is directly related to the overall improvement of quality of life and educational attainment, reduction in child mortality, the rise in family planning with greater availability of contraceptive methods and the increasing participation of women in the labour market.[39] The downturn in fertility rates did not occur uniformly among different socioeconomic groups of the population, being most marked for the wealthiest and for white women. Worldwide, fertility decline was universal, from an average of 4.5 births per woman in 1970–75 to 2.5 births per woman in 2010–15. The largest reductions took place in Asia.[40]

Birth intervals are also increasing globally. A study using data from demographic and health surveys (DHS) from 72 countries, ranging in date from 1985 to 2008, showed an overall median birth interval of 32.1 months, with marked heterogeneity between countries.[41] Brazil, in 1996, had longer median birth intervals than the Latin American and Caribbean region, but still shorter than observed in the Pelotas 1993 cohort (31.5, 29.9 and 48.3 months, respectively). An analysis conducted in 66 countries between 1965 and 2014 showed that all major world regions had substantial increases in birth intervals. The largest increases were observed in sub-Saharan Africa and in Latin America and the Caribbean.[42] Consistent with the international literature, birth intervals in our study increased markedly, mainly among the poorest; however, white and the wealthiest women still reported the longest birth intervals in 2015.[41] Correspondingly, the frequency of short intervals (<36 months) declined sharply. Due to very well-known maternal and child health risks associated with short birth intervals,[3–5,43] such a reduction can be regarded as a positive public health accomplishment.

The profile of Brazilian mothers has undergone significant changes over recent decades, with an increase in the percentage of mothers who start reproducing at later ages, a predominance of primiparous mothers and sustained increase in the rates of caesarean deliveries.[44,45] Even though the proportion of adolescent mothers remained stable at around 15%, the percentage of mothers aged ≥30 years increased from about 25% in 1982 to almost 40% in 2015.[23] Along with these changes, substantial improvements were observed in infant survival and—to a lesser extent—in maternal health indicators. In contrast to such improvements, there have been marked increases in preterm deliveries and stagnation in the prevalence of low birthweight.[17] The city of Pelotas followed this trend, as described in the accompanying articles in this journal[23,44] Specifically, preterm births rose from 6.3% in 1982 to 15.5% in 2015.[46] The increased prevalence of histories of preterm births among the poor, and of low birthweight among the rich, are consistent with the results for the children born in the four cohorts[46] and are likely related to changes in obstetric practices, particularly the remarkable increase in caesarean sections.

Rates of multiple births also vary considerably across the world. Among developed countries, twinning rates are between 2% and 4% of all births.[47] Smits and Monden showed an average incidence of twinning across 75 low- and middle-income countries of 1.3%, with Benin and Vietnam being at the ends of the distribution (2.8% and 0.6%, respectively).[48] Given the relative stability of monozygotic twinning rates across human populations, the variation observed among the countries is almost completely due to variation in dizygotic twinning.[49] Recent decades have seen a major increase in the number and rate of multiple births in many developed countries.[13,48] A combination of factors contributed to this increase, particularly the growing use of assisted reproductive technology, which is more likely to result directly in multifetal gestations, as well as in older age at the time of conception, when multifetal gestations are more likely to occur naturally.[50] Among low- and middle-income countries, the changes in twinning rates over time have been small, suggesting that the influence of fertility treatments is still low in these countries.[50] In Brazil, data from vital statistics showed a steady increase of multiple birth rates in recent decades, from 1.49% in 1994 to 2.09% in 2015.[51] Our data from Pelotas not only confirm the national trends, albeit at higher rates than for Brazil as a whole, but also provide information on inequalities which are not readily available from secondary statistics. We showed that the increase in multiple births was restricted to high-income, white women, whereas levels remained stable for poor and for black women. This is certainly aligned to older age at the time of conception and the use of assisted reproductive technology.

The main strengths of our study include the use of consistently collected information from large population-based samples of women reflecting the socioeconomic spectrum in a middle-sized city, the high response rates and the availability of comparable variables in all four Pelotas cohort studies. Unfortunately, all outcome variables were assessed by maternal recall and as such may be affected by information bias. In addition, data on zygosity and use of fertility treatments were not available, preventing further exploration of the impact of these factors on multiple birth incidence in the city. The four cohorts are based on the date of delivery rather than the date of conception. This raises the possibility of fixed cohort bias,[52] but given that none of the variables under study is affected by seasonality, it is unlikely that our results were affected.

In the 33 years covered by the Pelotas cohort studies, substantial progress was observed in maternal and child health indicators.[46,53–55] Positive trends included reduced parity and increased birth intervals. On the negative side, reports of previous preterm and low birthweight deliveries became more frequent. Socioeconomic and ethnic group inequalities were narrowed down for some and increased for other indicators, but remain important for most indicators, indicating the need for further pro-equity interventions. Our results show that socioeconomic inequalities in health are dynamic, varying over time and between generations within the same city.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Centre, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centres of Excellence (PRONEX), Brazilian National Council for Scientific and Technological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Ana M B Menezes,[1] Aluisio J D Barros,[1] Andrea Dâmaso Bertoldi,[1] Diego G Bassani,[2] Helen Gonçalves,[1] Iná S Santos,[1] Joseph Murray,[1] Luciana Tovo-Rodrigues,[1] Maria Cecilia F Assunção,[1] Marlos Rodrigues Domingues[1] and Pedro R C Hallal.[1]

[1]Federal University of Pelotas, Brazil and [2]University of Toronto, Canada.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i54–i62
doi: 10.1093/ije/dyy129
Supplement Article

Supplement Article

Stillbirth, newborn and infant mortality: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Ana M B Menezes ,[1]* Fernando C Barros,[2] Bernardo L Horta ,[1] Alicia Matijasevich ,[1,3] Andréa Dâmaso Bertoldi ,[1] Paula D Oliveira ,[1] Cesar G Victora [1] and the Pelotas Cohorts Study Group**

[1]Post-Graduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil, [2]Post-Graduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil and [3]Department of Preventive Medicine, Faculty of Medicine FMUSP, University of São Paulo, São Paulo, Brazil

*Corresponding author. Federal University of Pelotas, Marechal Deodoro 1160, Pelotas-RS 96020-220, Brazil. E-mail: anamene.epi@gmail.com

**Members listed at end of article.

Editorial decision 22 May 2018; Accepted 4 June 2018

Abstract

Background: Infant-mortality rates have been declining in many low- and middle-income countries, including Brazil. Information on causes of death and on socio-economic inequalities is scarce.

Methods: Four birth cohorts were carried out in the city of Pelotas in 1982, 1993, 2004 and 2015, each including all hospital births in the calendar year. Surveillance in hospitals and vital registries, accompanied by interviews with doctors and families, detected fetal and infant deaths and ascertained their causes. Late-fetal (stillbirth)-, neonatal- and post-neonatal-death rates were calculated.

Results: All-cause and cause-specific death rates were reduced. During the study period, stillbirths fell by 47.8% (from 16.1 to 8.4 per 1000), neonatal mortality by 57.0% (from 20.1 to 8.7) and infant mortality by 62.0% (from 36.4 to 13.8). Perinatal causes were the leading causes of death in the four cohorts; deaths due to infectious diseases showed the largest reductions, with diarrhoea causing 25 deaths in 1982 and none in 2015. Late-fetal-, neonatal- and infant-mortality rates were higher for children born to Brown or Black women and to low-income women. Absolute socio-economic inequalities based on income—expressed in deaths per 1000 births—were reduced over time but relative inequalities—expressed as ratios of mortality rates—tended to remain stable.

Conclusion: The observed improvements are likely due to progress in social determinants of health and expansion of health care. In spite of progress, current levels remain substantially greater than those observed in high-income countries, and social and ethnic inequalities persist.

Key words: stillbirth, infant mortality, cohort studies, socio-economic factors, infant newborn

Key Messages

- There were important reductions in fetal and child death rates during 1982–2015: stillbirths fell by 47.8%, neonatal mortality by 57.0% and infant mortality by 62.0%.
- The number of infant deaths in the city fell from 215 in 1982 to 59 in 2015, and the infant-mortality rate fell from 36.4 to 13.8/1000 live births, respectively.
- Deaths due to infectious diseases showed the largest reductions and, in 2015, there were no deaths due to diarrhoea compared with 25 in 1982.
- Absolute socio-economic inequalities in mortality were reduced over time, but relative inequalities tended to remain stable.

Introduction

Infant-mortality rates for Brazil have declined by 80.4% in the last three decades, from 71.3 per 1000 live births in 1982 to 14.0 in 2015.[1] As a consequence, Brazil reached the fourth Millennium Development Goal, which required a two-thirds reduction between 1990 and 2015 of the mortality of children aged under 5 years.[2–4]

Neonatal mortality also fell by 63.4%, from 33.4 to 8.2 deaths per 1000 between 1982 and 2015, therefore showing a slower rate of reduction than infant or under-5 mortality. Among neonatal deaths, the reduction was faster for late-neonatal (7–28 days) than for early-neonatal (0–6 days) mortality.[5] These findings are consistent with information on time trends in causes of death, which show a marked decline in infectious diseases, coupled with a relative increase in the proportion of deaths due to complications of prematurity.[6,7]

Unlike data on neonatal, infant and under-5 mortality, which are widely available from vital registration or demographic surveys, few low- and middle-income countries (LMICs) are able to measure fetal mortality, and thus existing estimates are largely based on modelling. Blencowe *et al.*[8] estimated that the late-fetal-mortality rate (28 weeks' gestation or more) for the whole of Latin America fell from 11.3 per 1000 total births in 1982 to 8.2 in 2015—a reduction of 27.4%. A systematic review of fetal mortality in Brazil showed poor quality in the routine information system, with low coverage of the information system and—even when records were present—a high frequency of missing information on causes of death and maternal characteristics. Most deaths that were reported fell into the antepartum category.[9]

The important decline in child mortality in Brazil was accompanied by reductions in geographic and socio-economic inequalities,[7] but these are still far from being eliminated. In particular, mortality rates for children living in urban slums or for indigenous children still remain well above those among the rest of the population.[10]

In order to test the hypothesis that mortality rates are falling and that inequalities are being reduced, we report on the levels and causes of late-fetal, newborn and infant mortality in the city of Pelotas in Southern Brazil, where four population-based birth cohort studies were carried out in the years of 1982, 1993, 2004 and 2015. The existence of four comparable studies over more than three decades is unique and provides the opportunity of studying not only overall trends, but also trends in socio-economic inequalities, which is not possible to do using other data sources.

Earlier publication compared trends up to the 2004 cohort.[11] We focus on how mortality levels and the degree of socio-economic inequalities have evolved over more than three decades.

Methods

Each cohort recruited all hospital births that occurred in the calendar years of 1982, 1993, 2004 and 2015. A surveillance system was set up to detect all infant deaths. In the first two cohorts, there was evidence that the coverage of death registration in the city was incomplete. Therefore, during 1982–83 and 1993–94, our research team made fortnightly visits to all emergency departments, paediatric wards and intensive-care units, cemeteries and the city's vital registration office. We found that 24% of the deaths to children born in 1982 and 5.4% of those born in 1993 had not been registered.[12] In 2004 and 2015, the vital registration system had full coverage and a municipal audit committee for infant deaths was in place, so that it was not necessary to set up our own surveillance system. Once deaths were identified, we obtained copies of the death certificates and reviewed hospital case notes. If necessary, we interviewed the paediatricians and obstetricians (for late-fetal deaths), as well as the child's parents.

Late-fetal deaths were classified as antepartum or intrapartum; there was no attempt to identify the causes of death. In 1982 and 1993, the analyses of fetal deaths were restricted to fetuses with gestational age of 28 or more weeks and/or a weight of 1000 g or more. In 2004 and 2015, information was also collected on fetal deaths occurring between 20 and 27 weeks' gestation and/or a weight of 500 g or more, but the analyses presented here is based on ≥28 weeks' gestation. In 1982 and 1993, gestational age was based on the date of the last menstrual period provided by the mother whereas, in 2004 and 2015, we adopted the best obstetric estimate, based primarily on ultrasound and secondarily on the last menstrual period, when ultrasound information was not available. Birthweights were measured using paediatric scales with a precision of 100 g that were regularly calibrated by the research team. Details on the assessment of gestational age and birthweight in the four cohorts are available elsewhere.[13,14]

Causes of infant deaths were classified independently by two physicians based on the death certificates, hospital case notes and, when applicable, the notes from interviews with doctors and families. When there was disagreement between the two reviewers, a senior paediatrician (F.B.) acted as an arbiter to establish the cause. In 1982, because information on causes of death was often poor, deaths were grouped according to the Wigglesworth classification, with slight modifications.[15] The following groups were used: perinatal causes, malformations, diarrhoea, respiratory-tract infections, other infections and other causes; the latter also included ill-defined causes. In 1993, ICD9 was used to classify causes of death and, in 2004 and 2015, the ICD10 classification was used.[15–17] For consistency with the 1982 cohort results, the same groups of causes were used for the later cohorts.

The following mortality rates were calculated, with their respective 95% confidence intervals (CIs), using standard international definitions.[18,19] Late-fetal- and perinatal-mortality rates were expressed for 1000 total births; all other rates had 1000 live births as the denominator. Analyses of mortality rates were stratified by family-income terciles, maternal skin colour (White, Brown or Black) and sex of the child. Analyses according to family-income quintiles were carried out initially but, due to the small number of deaths in some categories, this variable was re-coded into terciles. Further information on the stratification variables is available elsewhere.[13]

Data analyses included chi-squared tests for heterogeneity and linear trends. Poisson regression with robust variance was used to analyse ratios of mortality rates according to the categories of explanatory variables across the four cohorts, when there was no statistical evidence of an interaction with the cohort year.[20] If there was an interaction, we present the rate ratios separately for each cohort. Prevalence ratios for neonatal and infant mortality in the 1993, 2004 by and 2015 cohorts, using the 1982 cohort as reference, were evaluated through Poisson regression adjusted for gestational age.

The slope index of inequality and concentration index were used to assess income-related disparities.[21] The slope index (SII) represents the absolute difference in the fitted value of the health indicator between the highest (score of 1) and the lowest (score of 0) values of the socio-economic indicator rank; it is expressed in percentage points. The concentration index (CIX) is expressed on a scale from –100 to +100, with zero representing equal distribution of the attribute across the wealth scale. Positive values indicate that the outcome is more common among the rich, whereas negative values indicate higher levels among the poor.[21] Stata software 13 was used for the analyses.[22]

Ethical approval for studies was not required in Brazil until 1996. The 2004 study was approved by the Ethics Committee of the School of Medicine and the 2015 by the School of Physical Education, Federal University of Pelotas, and written consent was obtained from the mothers. All datasets were anonymized for the present analyses.

Results

The number of live births fell by nearly one-third from 1982 to 2015 (Table 1). All death rates were reduced, except for late-neonatal deaths, for which there was no statistical evidence of a decline. The late-fetal-death rate (≥28 weeks' gestation) fell by 47.8% from 16.1 to 8.4 per 1000 total births. In 2004 and 2015, it was also possible to calculate the fetal-death rates starting at a gestational age of 20 weeks, which were equal to 13.1 (95% CI 9.7–16.40) in 2004 and 12.5 (95% CI 9.2–15.8) in 2015. The antepartum late-fetal-death rate fell from 13.1 (10.3–16.0) to 8.1 (5.4–10.8) from 1982 to 2015—a reduction of 38.2%. In contrast, intrapartum deaths fell by 90% from 2.5 to 0.2 per 1000 from 1982 to 2004, when only one such death took place. Neonatal mortality fell from 20.1 to 8.7—a reduction of 57.0%. Infant mortality fell by 62.0%, from 36.4 to 13.8 (Table 1), whereas the absolute number of infant deaths dropped from 215 to 59 in the city.

Tables 2–4 show late-fetal-, neonatal- and infant-mortality rates according to sex, maternal skin colour and family income in each cohort. The supplementary materials (Supplementary Tables 1–3, available as Supplementary data at *IJE* online) include the absolute numbers of deaths for all analyses reported in this paper, whereas results for perinatal mortality are shown in Supplementary Table 4 and Supplementary Table 4a, available as Supplementary data at *IJE* online, and those for post-neonatal mortality in Supplementary Table 5 and Supplementary Table 5a,

Table 1. Late-fetal-, perinatal-, neonatal- and infant-mortality rates in four birth cohorts, Pelotas, Brazil

	Birth cohorts (years)				
	1982	1993	2004	2015	*p*
Number of births*	6011	5304	4272	4311	–
Number of live births	5914	5249	4231	4275	–
Late-fetal deaths*					
Number	97	55	41	36	<0.001
Fetal-mortality rate[a] (1000 total births)	16.1	10.4	9.6	8.4	
95% CI	13.0–19.3	7.6–13.1	6.7–12.5	5.6–11.0	
Early-neonatal deaths					<0.001
Number	97	62	38	27	
Early-neonatal-mortality rate[b] (1000 live births)	16.4	11.8	9.0	6.3	
95% CI	13.0–19.5	8.9–14.7	6.2–11.8	3.9–8.7	
Perinatal deaths (fetal* + early-neonatal)					–
Number	194	117	79	63	<0.001
Perinatal-mortality rate (1000 total births)	32.3	22.1	18.5	14.6	
95% CI	27.7–36.5	18.1–26.0	14.5–22.5	11.0–18.2	
Neonatal deaths					<0.001
Number	119	75	52	37	
Neonatal-mortality rate (1000 live births)[c]	20.1	14.3	12.3	8.7	
95% CI	16.5–23.7	11.1–17.5	9.0–15.6	5.8–11.4	
Late-neonatal deaths					0.317
Number	22	13	14	10	
Late-neonatal-mortality rate (1000 live births)[d]	3.7	2.5	3.3	2.3	
95% CI	2.2–5.3	1.1–3.8	1.6–5.0	0.9–3.8	
Infant deaths					<0.001
Number	215	111	82	59	
Infant-mortality rate (1000 live births)[e]	36.4	21.1	19.4	13.8	
95% CI	31.6–41.1	17.3–25.0	15.2–23.5	10.3–17.3	

*Gestational age ≥28 weeks; CI, confidence interval; total number of births considering gestational age ≥20 weeks is 4287 (2004) and 4329 (2015).
[a]Total stillbirths/total births.
[b]Total deaths before 7 full days of life/total births.
[c]Deaths occurred from the first day to 28 incomplete days after birth/total live births.
[d]Deaths occurred after 7 full days and before 28 full days of life/total live births.
[e]Deaths during the first year of life/total live births.
p-value: χ^2 for trend.

available as Supplementary data at *IJE online*. Trends in absolute inequalities are described at the end of this section.

Table 2 shows late-fetal-mortality rates in each cohort according to the explanatory variables. The pooled mortality sex ratio was equal to 1.07 (95% CI 0.82–1.39) for boys relative to girls, and there was no evidence that the ratio changed over time ($P = 0.48$ for the interaction with cohort year). In contrast, there was statistical evidence ($P = 0.013$) that late-fetal mortality according to maternal skin colour changed over time: the ratios for Black or Brown skin colour, relative to White, were 1.26 (95% CI 0.78–2.03), 1.93 (1.12–3.34), 2.31 (1.26–4.26) and 3.16 (1.64–6.08) in 1982, 1993, 2004 and 2015, respectively. Late-fetal-mortality rates remained stable at around 20 per 1000 for Black women, but fell by two-thirds for White mothers.

Regarding family income (Table 2), the lowest mortality rates in all cohorts were observed in the richest tercile, for which the rate was already low (4.5 per 1000) in 1982. Otherwise, patterns were not very clear, with the ratios between the poorest and richest terciles being greater than three times in the first and last cohorts, and smaller in 1993 and 2004. The only group with a substantial decline in mortality was the poorest tercile.

Neonatal-mortality rates are shown in Table 3. The associations between mortality and sex, skin colour and income did not change over time; interaction terms with cohort year had *P*-levels of 0.79, 0.56 and 0.46, respectively. Thus, results for the four cohorts were pooled. Newborn deaths were 1.44 (95% CI 1.13–1.82) times more common among boys than girls and 1.49 (1.16–1.91) times higher for children born to Black or Brown mothers than for those

Table 2. Late-fetal-mortality rate (gestational age ≥28 weeks) according to sex, maternal skin colour and socio-economic status in four birth cohorts, Pelotas, Brazil

	Late-fetal-mortality rate per 1000 total births (95% CI)				
	1982	1993	2004	2015	p*
Sex	$p = 0.950$	$p = 0.612$	$p = 0.578$	$p = 0.210$	
Males	15.9 (11.5–20.3)	10.3 (6.4–14.1)	8.1 (4.4–11.9)	10.0 (5.9–14.2)	0.024
Females	16.1 (11.5–20.6)	9.0 (5.4–12.6)	9.7 (5.5–14.0)	6.6 (3.1–10.0)	0.002
Maternal skin colour	$p = 0.345$	$p = 0.044$	$p = 0.018$	$p < 0.001$	
White	15.4 (12.0–18.9)	8.6 (5.7–11.4)	7.1 (4.1–10.0)	5.2 (2.6–7.7)	<0.001
Brown	19.4 (11.2–27.7)[a]	12.7 (0.0–26.9)	13.4 (0.3–26.4)	10.6 (2.1–18.9)	0.756
Black		17.5 (9.2–25.7)	17.4 (8.7–26.2)	21.4 (10.3–32.6)	0.856
Family income (tertiles)	$p < 0.001$*	$p = 0.653$*	$p = 0.135$*	$p = 0.008$*	
T1 (poorest)	34.4 (26.5–42.3)	10.9 (5.7–16.1)	9.7 (4.6–14.7)	12.4 (6.8–17.9)	<0.001
T2	9.0 (4.9–13.1)	11.0 (6.2–15.8)	15.0 (8.6–21.3)	8.9 (3.9–13.9)	0.651
T3 (richest)	4.5 (1.6–7.5)	9.4 (4.9–13.8)	4.2 (0.8–7.6)	3.5 (0.4–6.6)	0.398

p-value: χ^2 test for heterogeneity.
*p-value: χ^2 for trend.
[a]Black and Brown were combined.

Table 3. Neonatal-mortality rate according sex, maternal skin colour and socio-economic status in four birth cohorts, Pelotas, Brazil

	Neonatal-mortality rate per 1000 live births				
	1982	1993	2004	2015	p*
Sex	$p = 0.169$	$p = 0.029$	$p = 0.093$	$p = 0.453$	
Males	22.4 (17.1–27.7)	17.7 (12.6–22.7)	15.0 (9.9–20.1)	9.7 (5.6–13.8)	<0.001
Females	17.4 (12.6–22.2)	10.6 (6.7–14.5)	9.3 (5.2–13.5)	7.6 (3.9–11.3)	0.001
Maternal skin colour	$p = 0.521$	$p = 0.068$	$p = 0.061$	$p = 0.261$	
White	19.6 (15.7–23.5)	12.3 (8.9–15.7)	10.0 (6.5–13.5)	7.5 (4.4–10.5)	<0.001
Brown	22.6 (13.7–31.6)[a]	25.6 (5.3–45.9)	13.6 (0.3–26.8)	8.9 (1.1–16.7)	0.265
Black		19.9 (11.0–28.8)	20.1 (10.6–29.6)	14.1 (4.9–23.2)	0.074
Family income (tertiles)	$p = 0.008$*	$p = 0.014$*	$p = 0.094$*	$p = 0.1061$*	
T1 (poorest)	23.9 (17.2–30.7)	18.8 (12.0–25.5)	16.8 (10.1–23.4)	10.5 (5.4–15.7)	0.003
T2	24.3 (17.5–31.0)	14.5 (8.9–19.9)	10.1 (4.9–15.4)	10.5 (5.0–15.9)	0.001
T3 (richest)	12.2 (7.3–17.0)	8.9 (4.6–13.2)	9.9 (4.7–15.0)	4.9 (1.3–8.6)	0.050

p-value: χ^2 test for heterogeneity.
*p-value: χ^2 for trend.
[a]Black and Brown were combined.

born to White women. Regarding family income, pooled rates in the poorest tercile were 1.96 (1.44–2.67) times higher than in the richest tercile; the rate ratio between the middle and richest terciles was 1.69 (1.23–2.32).

Regarding infant mortality (Table 4), rates were 1.21 (1.10–1.45) higher for boys than for girls, with no evidence of change over time ($P = 0.58$ for interaction with cohort year). There was also no evidence of a change in the ethnic gradient over time ($P = 0.97$), with children born to Black or Brown mothers showing 1.76 (1.45–2.13) times higher risk than those born to White mothers. For income, the pooled ratio of mortality in the poorest relative to the richest tercile was 3.11 (2.42–4.01) and that between the middle and richest tercile 1.85 (1.41–2.43). There was no interaction between income and cohort year ($P = 0.25$).

Because of the important increase in preterm deliveries during the study period, we assessed the estimated change in neonatal and infant mortality, adjusting for the observed trends in gestational age distribution through Poisson regression (Supplementary Table 6, available as Supplementary data at *IJE* online). In the unadjusted analyses, the neonatal mortality in 2015 was equal to 43% (prevalence ratio of 0.43) of the level observed in 1982. After adjustment for the gestational age distribution, the reduction was even sharper: mortality in 2015 was equal to 33% of the 1982 rate. Similar results were obtained for

Table 4. Infant-mortality rate according sex, maternal skin colour and socio-economic status in four birth cohorts, Pelotas, Brazil

	Infant-mortality rate per 1000 live births (95% CI)				
	1982	1993	2004	2015	p*
Sex	$p = 0.260$	$p = 0.044$	$p = 0.322$	$p = 0.820$	
Males	38.9 (32.0–45.7)	25.0 (19.0–31.0)	21.4 (15.3–27.5)	13.3 (8.6–18.2)	<0.001
Females	33.4 (26.8–39.9)	17.0 (12.1–21.9)	17.2 (11.5–22.9)	14.2 (9.2–19.3)	<0.001
Maternal skin colour	$p < 0.001$	$p = 0.013$	$p = 0.008$	$p = 0.068$	
White	32.2 (27.2–37.1)	18.0 (13.9–22.1)	15.5 (11.2–19.9)	11.7 (7.9–15.5)	<0.001
Brown	55.7 (41.8–69.5)[a]	34.2 (10.9–57.5)	23.7 (6.3–41.1)	14.3 (4.4–24.1)	0.069
Black		31.4 (20.3–42.4)	31.9 (20.1–43.8)	23.5 (11.7–35.2)	0.001
Family income (tertiles)	$p < 0.001$*	$p < 0.001$*	$p = 0.002$*	$p = 0.009$*	
T1 (poorest)	61.6 (51.0–72.3)	30.5 (21.9–39.0)	28.7 (20.0–37.3)	19.1 (12.2–26.0)	<0.001
T2	30.8 (23.2–38.4)	23.4 (16.4–30.3)	16.7 (9.9–23.4)	14.2 (7.9–20.5)	<0.001
T3 (richest)	16.7 (11.1–22.4)	9.5 (5.0–13.9)	12.7 (6.9–18.5)	7.8 (3.2–12.3)	0.040

p-value: χ^2 test for heterogeneity.
*p-value: χ^2 for trend.
[a]Black and Brown were combined.

Table 5. Number of deaths and cause-specific infant-mortality rates 1982–2015

	1982 *N* rate per 1000 live births (95% CI)	1993 *N* rate per 1000 live births (95% CI)	2004 *N* rate per 1000 live births (95% CI)	2015 *N* rate per 1000 live births (95% CI)	p
Perinatal	92 15.6 (12.4–18.7)	57 10.9 (8.1–13.7)	41 9.7 (6.7–12.6)	36 8.4 (5.7–11.2)	0.001
Congenital malformations	27 4.6 (2.8–6.3)	25 4.8 (2.9–6.6)	8 1.9 (0.6–3.2)	7 1.6 (0.4–2.8)	0.002
Diarrhoea	25 4.2 (2.6–5.9)	9 1.7 (0.6–2.8)	1 0.2 (0.0–0.7)	0 0.00	<0.001
Respiratory infections	25 4.2 (2.6–5.9)	7 1.3 (0.3–2.3)	13 3.1 (1.4–4.7)	4 0.9 (0.0–1.9)	0.007
Other infections	18 3.0 (1.6–4.4)	1 0.2 (0.0–0.6)	5 1.2 (0.1–2.2)	2 0.5 (0.0–1.1)	0.002
Other causes or ill-defined	28 4.7 (3.0–6.4)	12 2.3 (1.0–3.6)	14 3.3 (1.6–5.0)	10 2.3 (0.9–3.8)	0.069
Total	215	111	82	59	

p-value: χ^2 for trend.

infant mortality, with prevalence ratios of 0.38 in the unadjusted analyses and 0.30 after adjustment.

Income-related inequalities in mortality were assessed through the slope and concentration indices. For late-fetal mortality, the slope index declined from –47.3 (95% CI −62.0 to –32.5) deaths per 1000 total births in 1982 to –13.3 (–23.2 to –3.4) in 2015, showing a marked reduction in absolute inequalities. There was not much evidence of a change in relative inequalities, as the concentration index was equal to –42.9 (–53.3 to –32.5) in 1982 and –18.5 (–35.9 to –10.9) in 2015, but the CIs overlapped. None of the two indices presented important changes for neonatal mortality; the slope index was equal to –17.4 (–29.9 to –5.0) in 1982 and –8.3 (−17.9 to 13.2) in 2015, and the concentration index –11.0 (–20.0 to –2.0) and –19.0 (–36.1 to –1.8), respectively. Lastly, absolute inequalities in infant mortality were markedly reduced with slope indices of –68.7 (–88.4 to –49.0) in 1982 and –17.1 (–30.0 to –4.3) in 2015, but relative inequalities remained almost unchanged with concentration indices of –25.0 (–31.8 to –18.2) and –24.3 (–38.0 to –10.7), respectively. These results for relative inequalities, based on the concentration index, are consistent with the absence of an interaction between income and cohort year in the multiplicative Poisson models.

Table 5 shows important reductions in the absolute number of causes of death, as well as mortality rates, for all causes. From 1982 to 2015, mortality rates fell by 47% for perinatal causes and 64% for malformations. Diarrhoea deaths were eliminated, and there were reductions of 79% for respiratory infections and 87% for other infections. Other or ill-defined causes, including sudden infant deaths, fell by 51%.

Discussion

During the study period, all-cause and cause-specific mortality rates were reduced; stillbirths fell by 47.8%, neonatal mortality by 57% and infant mortality by 62%. The leading causes of death were perinatal conditions and the largest reductions were observed for infectious diseases. Children born to Brown or Black women and to low-income women showed the highest late-fetal-, neonatal- and infant-mortality rates; although absolute socio-economic inequalities were reduced over time, relative inequalities remained stable.

Few studies on time trends in stillbirths are available from LMICs. Our results suggest that the decline in late-fetal deaths was slightly slower than for neonatal deaths, and markedly slower than for infant deaths as a whole. Much of the decline was due to the virtual elimination of intrapartum deaths—possibly one of the few advantages of having a caesarean-section rate above 60% in 2015.[23,24] The 2015 rate of 8.4 stillbirths per 1000 is very similar to that of 8.2 estimated for Latin America as a whole,[8] but remains over twice as high as the rate of 3.5 per 1000 estimated for high-income countries.[25] It is striking that, whereas late-fetal mortality fell by more than 60% for gestations of White mothers, it remained stable over time at around 20 per 1000 for Black women. Unfortunately, we have no information on causes of stillbirths. It is well known that congenital syphilis remains a problem in Brazil,[26,27] but the Zika virus epidemic never reached Pelotas. In 2015, stillbirths accounted for 38% (36 over 36 plus 59) deaths occurring from 28 weeks' gestation to the first birthday in Pelotas. Increasing the visibility of stillbirths is essential for raising political awareness of the need to prevent them.[28]

The neonatal-mortality rate in 2015 of 8.7 per 1000 live births was close to the rate of 8.2 estimated for Brazil.[1] In contrast, the decline observed in Pelotas since 1982 (from 20.1 to 8.7) was much slower than that recorded for the country as a whole (from 33.4 to 8.2).[1] This is likely related to lower levels in Pelotas in 1982, as well as to the fact that socio-economic standards and availability of health care in Pelotas were substantially ahead of other regions of the country in the 1980s. Over time, previously less developed states caught up in terms of economic growth and of universal access to health care, particularly from 1989 when the Unified Health System was created.[29] There is evidence of an important increase in preterm deliveries, which has been attributed—at least in part—to the extremely high caesarean-section rates.[7,30–32] The preterm epidemic may have contributed to the relatively low rate of decline in neonatal deaths in Pelotas. Our 2015 neonatal-mortality rate is similar to that observed in Latin America as a whole, but still four times larger than that recorded in high-income countries in Western Europe.[1]

Infant mortality in Pelotas fell by 62.0% over the study period, from 36.4 to 13.8 per 1000 live births. The size of this reduction becomes more palpable in absolute numbers: 215 annual deaths in 1982 in a city of 230 000 inhabitants, compared with 59 deaths in 2015 for 340 000 inhabitants; the decline in the number of births, from about 6000 to just over 4000, has also played a role, but the size of the reduction remains impressive. As for neonatal deaths, the 62.0% reduction in infant mortality was slower than that of 80.5% observed for Brazil as a whole. Infant mortality in Pelotas remains about five times higher than in Western Europe, and at similar rates to Latin America and the Caribbean,[1] though higher than the rates observed in our South American neighbours Uruguay and Argentina—9/1000 and 11/1000, respectively.[1]

Adjustment for the gestational age distribution in each cohort suggested that the declines in neonatal and mortality would be even more marked in the absence of the rising trend in preterm births in the city.[14]

Our data on cause-specific mortality since the 1980s are unique. The data reveal the huge reduction in infectious diseases, in particular the eradication of diarrhoea deaths. This decline is similar to what has been observed over a shorter time period in Brazil.[7] Our analyses of hospitalizations in the four cohorts[33] show similar declining trends for infectious diseases.

Our analyses of inequalities confirmed the higher risk of mortality associated with children born to women of low family income and for afro-descendants for late-fetal, neonatal and infant mortality. Boys were at higher risk of neonatal and infant mortality, but not of late-fetal mortality, than girls. Late-fetal-death rates fell faster for White mothers than for those with Black or Brown skin colour, which is possibly associated with better and earlier access to quality antenatal care.[23] In contrast, fetal mortality remained unchanged for gestations of women with Black or Brown skin colour—a finding that merits further research.

Trends over time in absolute wealth-related inequalities, expressed as differences in terms of deaths per 1000, were reduced for the three mortality indicators, particularly for infant mortality. In contrast, relative inequality—expressed as the ratios of mortality rates—remained constant. This apparent discrepancy in findings is common when rates are falling for all groups, and mortality levels among the wealthy still have scope for reduction, as was the case in 1982.[34] In terms of absolute differences, it is quite remarkable that, as expressed by the slope index, there were 69 more deaths per 1000 at the bottom than at the top of the income scale in 1982, and this difference fell to 17 by 2015. A marked reduction in wealth-related inequalities was also observed for Brazil as a whole in the past couple of decades.[7]

The strengths of the present analyses include the population-based nature of the four cohorts and the consistency of methods used over a 33-year period. The limitations include the relatively small number of deaths, particularly fetal deaths and deaths due to specific causes. Nevertheless, the low *P*-levels for analyses where disparities were present (e.g. by income in the early cohorts) suggests that statistical power was adequate for most purposes. A second limitation includes the changes in definition over time for fetal deaths as, in 1982, only deaths to fetuses with 28 weeks' or longer gestational age or a birthweight of 1000 g were recorded, in contrast to the later cohorts in which 20 weeks and 500 g were the cut-offs. This limitation was overcome by restricting all analyses to late-fetal deaths, complying with the 1982 definition. Fetal-mortality rates would evidently be higher had the current definition been adopted. Thirdly, information on gestational age was not comparable in the four cohorts as, in 1982 and 1993, it was based on the date on the last menstrual period and, in 2004 and 2015, it was derived primarily through obstetric ultrasound; in the present analyses, information on gestational age was only used for the definition of fetal deaths and it is unlikely that the important reduction in these rates was due to such methodological differences.

Another limitation is the information on the causes of deaths, which could only be coded in broad categories due to the lack of autopsies and to the changes in the International Classification of Diseases (ICD) codes over time; the categories used for the classification in 1982 had to be maintained for comparability.[35] Supplementary Box 1, available as Supplementary data at *IJE* online, shows the ICD9 and 10 codes. Lastly, Brazil was suffering from hyperinflation in 1993, with monthly rates close to 100% in some months, and this affected the information in family income for this cohort.

A detailed analysis of which factors contributed to the decline in mortality and reduction in absolute inequalities is beyond the scope of the present analyses. A review of child-mortality trends in Brazil as a whole suggested that progress may be explained by five sets of determinants: '(a) socioeconomic and demographic changes (economic growth, reduction in income disparities between the poorest and wealthiest populations, urbanization, improved education of women, and decreased fertility rates); (b) interventions outside the health sector (conditional cash transfer programs and improvements in water and sanitation); (c) vertical health programs in the 1980s (promotion of breastfeeding, oral rehydration, and immunizations); (d) creation of a tax-funded national health service in 1988 (coverage of which expanded to reach the poorest areas of the country through the Family Health Program in the mid-1990s); and (e) implementation of many national and state-wide programmes to improve child health and child nutrition.'[7]

The accompanying articles in this supplement on the Pelotas cohorts show the likely contribution of positive changes in socio-economic status, women's education, fertility, birth intervals and access to care.[13,23,36,37] On the other hand, there has been an increase in preterm births, which is likely to have precluded an even faster decline in mortality rates; the prevalence of low birthweight remained stable over the three decades.[14]

Substantial progress has been achieved, but current mortality levels in Pelotas remain three to four times higher than in high-income countries, whereas ethnic and social inequalities remain strong. Continued monitoring of mortality levels and inequalities is essential for overcoming this situation.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Center, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centers of Excellence (PRONEX), Brazilian National Council for Scientific and Tehcnological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Aluisio J D Barros,[1] Diego G Bassani,[2] Fernando C Wehrmeister,[1] Helen Gonçalves,[1] Iná S Santos,[1] Joseph Murray,[1] Luciana Tovo-Rodrigues,[1] Maria Cecilia F Assunção,[1] Mariangela F Silveira,[1] Marlos Rodrigues Domingues[1] and Pedro R C Hallal.[1]

[1]Federal University of Pelotas, Brazil and [2]University of Toronto, Canada.

Conflict of interest: None declared.

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IJEA

International Journal of Epidemiology, 2019, i72–i79
doi: 10.1093/ije/dyy159
Supplement Article

Supplement Article

Breastfeeding exclusivity and duration: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Iná S Santos,[1] Fernando C Barros,[2] Bernardo L Horta,[1] Ana M B Menezes,[1] Diego Bassani,[3] Luciana Tovo-Rodrigues,[1] Natália P Lima,[1] Cesar G Victora[1]* and the Pelotas Cohorts Study Group**

[1]Post Graduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil, [2]Post-Graduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil and [3]Department of Pediatrics, Hospital for Sick Children, University of Toronto, Toronto, ON, Canada

*Corresponding author. Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil. E-mail: cvictora@gmail.com
**Members listed at end of article.

Editorial decision 27 June 2018; Accepted 8 October 2018

Abstract

Background: Brazil has made substantial improvements in the duration of breastfeeding. We use data from four population-based cohorts to examine how trends and inequalities in breastfeeding indicators changed over time in a Brazilian city.
Methods: Data from four birth cohorts, each including all births in a calendar year (1982, 1993, 2004 and 2015) in the city of Pelotas were used. Information on breastfeeding was collected when children were aged between 3 and 20 months. The prevalences of continued breastfeeding at 1 year of age and of exclusive breastfeeding at 3 months were calculated according to family income, maternal skin colour and sex.
Results: Prevalence of breastfeeding at 12 months increased from 16% to 41% in the 33-year period. The prevalence of exclusive breastfeeding at 3 months increased from 7% in 1993 to 45% in 2015. Increases in exclusive breastfeeding at 3 months were seen in all socioeconomic groups, but the 2015 rates remain highest (57.2%) among the women in the richest quintile, and lowest among those in the poorest quintile (34.6%). Black mothers were more likely to breastfeed at 12 months than Whites in the four cohorts. In the earlier cohorts, breastfeeding at 12 months was more common among the poor, but by 2015 these differences had disappeared.
Conclusions: There were important positive changes in breastfeeding practices during this period, but less than half of the children in 2015 were receiving the full benefits of breast milk. Improved breastfeeding practices are being adopted by high-income women to a greater extent than by poor women.

Key words: Breast feeding, exclusive breastfeeding, socioeconomic factors, cohort studies

Key Messages

- The prevalence of continued breastfeeding at 1 year in the 2015 Pelotas cohort (41%) was similar to the Brazilian national estimate in 2013 (45.4%). Prevalence of exclusive breastfeeding at 3 months of age was 45%.
- There were important positive changes in breastfeeding practices from 1982 to 2015, but less than half of the children in 2015 were receiving the full benefits of breast milk.
- Improved breastfeeding practices are being adopted by high-income women to a greater extent than by poor women. Promotion efforts should be reinforced for the latter group.

Introduction

The short- and long-term benefits of breastfeeding for both mothers and children are well documented. In the short term, breastfeeding—and in particular exclusive breastfeeding—protects against infectious diseases, especially diarrhoea and pneumonia.[1–4] In the long term, breastfeeding has been associated with lower risks of obesity and type 2 diabetes, increased intelligence in childhood, adolescence and adulthood and higher levels of formal education and income in adult life.[5,6]

In terms of maternal health, breastfeeding provides protection against breast cancer and contributes to increased birth spacing, while also potentially protecting against ovarian cancer and type 2 diabetes.[4] More recently, breastmilk has been recognized as a living substance containing stem and progenitor cells as well as oligosaccharides that promote the growth of a healthy microbiome and also present anti-infective properties.[4,7,8]

In spite of the well recognized benefits of breastfeeding, rates of early initiation of breastfeeding and prevalence of exclusive breastfeeding among infants aged less than 5 months in most low- and middle-income countries remain below 50%.[9] A previous analysis including the first three Pelotas birth cohorts (1982, 1993 and 2004) indicated an improvement in breastfeeding indicators. In those two decades, the proportion of 12-month-old children who were breastfed increased from 16% to 37% and the proportion of those exclusively breastfeeding at 3 months of age, which was null in 1982, reached 27% of the infants in 2004.[10] The objective of the present study was to assess whether these positive trends persisted when the results of the Pelotas 2015 Birth Cohort were incorporated in the analyses.

Methods

The four Pelotas Birth Cohorts (1982, 1993, 2004 and 2015) comprise about 20 000 participants. All newborns to mothers resident at the urban area of the municipality and delivered in all delivery wards in the city, between 1 January and 31 December of the corresponding year, were eligible to participate in the study. A total of 5914 newborns were enrolled in 1982, 5249 in 1993, 4231 in 2004 and 4275 in 2015, representing more than 99% of all births that occurred in Pelotas in those years.[11]

At the beginning of 1983, the 1982 cohort team tried to locate all the participants born between January and April 1982 ($n = 1916$), being able to locate 79.3% of that sample (mean age 11.3 months); the full cohort was re-visited in early 1984 through a census of all households in the city, when the follow-up rate increased to 87.2%. A sample of the 1993 cohort was followed up at 6 and 12 months ($n = 1460$). The sample included all low-birthweight newborns (<2500 g) and 20% of the remaining cohort members. At 6 and 12 months, 96.8% and 93.4%, respectively, of the intended samples were assessed. At 3 and 12 months of age, the cohort teams attempted to contact all infants that were part of the 2004 and 2015 birth cohorts. The follow-up rates in 2004 were 95.7% and 94.3%, respectively; and in 2015 were 97.2% and 95.4%. Supplementary Table 1, available as Supplementary data at *IJE* online, describes the sample size and timing of each follow-up for each cohort; more details are provided in the first article in this supplement.[11]

In the four cohorts, mothers were interviewed at the hospital in the first 24 h after the delivery and the newborns were examined with standardized techniques and data collection instruments. Information was collected from the mother on social, demographic and health-related variables.[11] Home visits were carried at the ages described above, and information on the age when breastfeeding was stopped and on the introduction of complementary foods during first year of life was collected. Breastfeeding pattern in the first year of life was classified in four groups: exclusive breastfeeding (breastfed infants who did not receive any other fluids or solid foods); predominant breastfeeding (breastfed infants who received fluids such as water, tea or fruit juices, but were not fed solid or semi-solid foods); partial breastfeeding (infants who were fed breast milk complemented with other types of milk, such as cow's milk or formula, or with solid or semi-solid foods); and weaned infants (who were not breastfed). In 1982, questions were not asked about the use of water or tea, so that it was not possible to estimate the prevalence of exclusive breastfeeding.

Information on monthly family income, maternal skin colour (white, brown or black) and child sex obtained in the perinatal study constituted the independent variables in the analyses. Family income was divided in quintiles, with the first quintile including the poorest and the fifth quintile the wealthiest families. Ethnic group classification according to self-reported skin colour has been officially adopted in Brazil, and is supported by the Organized Black Movement which since the 1970s has advocated for disaggregation of all vital and health statistics according to skin colour.[12]

For the analyses, data of the 1993 cohort were weighted in order to account for the oversampling of low-birthweight infants. The prevalences of exclusive breastfeeding at 3 months of age and of continued breastfeeding at 1 year of age, according to independent variables, were calculated for each cohort. Chi-square tests were used to assess the association between breastfeeding and the independent variables. When appropriate, chi-square tests for linear trends in proportions were used to assess differences over time.

The slope index of inequality (SII) and concentration index (CIX) were calculated for family income in quintiles, to assess absolute and relative inequalities in prevalence of exclusive breastfeeding at 3 months of age and in continued breastfeeding at 1 year of age in the four cohorts.[13,14]

Results

At all ages, higher proportions of infants were breastfed in 2015 than in 1982 (Figure 1). Figure 2 shows breastfeeding patterns at 3 and 12 months of age. The improvement in prevalence of exclusive breastfeeding at 3 months was most evident. Data are not presented for 1982 because information on feeding child water or tea intake was not collected; the prevalence of either exclusive or predominant breastfeeding in this cohort was 37%, but it is safe to assume that the prevalence of exclusive breastfeeding was virtually zero as the standard practice was to feed children with water and tea from the first weeks of life. For the subsequent cohorts, prevalence of exclusive breastfeeding increased from 7% in 1993 to 27% in 2004 and 45% in 2015, corresponding to an increase of 67% in the prevalence of this practice in the most recent 11-year period. Partial breastfeeding remained relatively stable, reaching around 25% of all infants since 1993. There was a marked

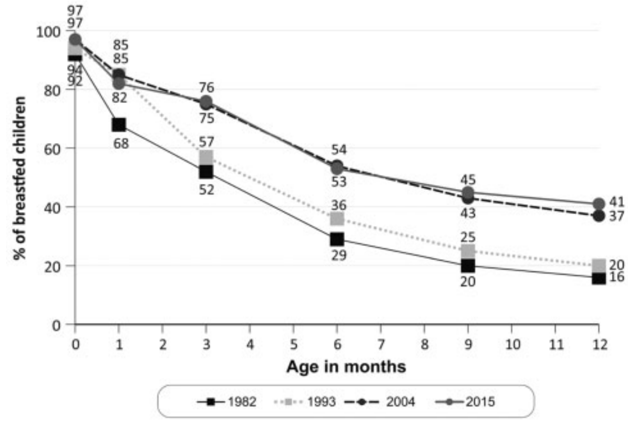

Figure 1. Prevalence of continued breastfeeding at different ages. Pelotas 1982, 1993, 2004 and 2015.

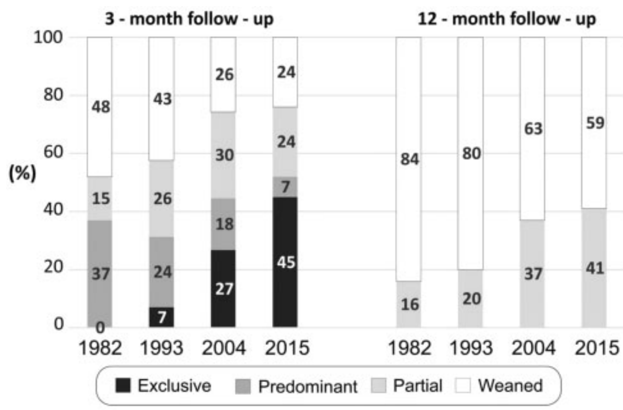

Figure 2. Breastfeeding patterns at ages 3 and 12 months. Pelotas, 1982, 1993, 2004, and 2015.

reduction in the proportion of fully weaned infants at 3 months of age, with the proportion of children receiving some form of breastfeeding in 1982, 1993, 200 and 2015 being 52%, 57%, 74% and 76%, respectively (*P* for linear trend <0.001). The prevalences of exclusive breastfeeding at 6 months were 0.5% in 1993, 6.5% in 2004 and 14.5% in 2015.

At 12 months, the prevalence of continued breastfeeding increased from 16% in 1982 to 20%, 37% and 41%, respectively, in 1993, 2004 and 2015 (Figure 2) (*P* for linear trend <0.001). The median durations of breastfeeding increased from 3.0 months in 1982 and 1993 to 6.0 and 6.9 months in 2004 and 2015, respectively. In the most recent cohort, few infants were fully weaned between 7 and 12 months, so that in spite of the median value of 6.9 months, the prevalence of breastfeeding at 12 months was 41%.

Table 1 shows the results for prevalence of exclusive breastfeeding at 3 months of age. As mentioned, exclusive breastfeeding in the 1982 cohort is assumed to be close to

Table 1. Prevalence of exclusive breastfeeding at 3 months according to family income, maternal skin colour and sex of the child. Pelotas, 1993, 2004, and 2015

Variables	Exclusive breastfeeding at 3 months of age,[a] *n* (range)		
	1993	2004	2015
Family income (quintiles)	$P = 0.025$*	$P < 0.001$*	$P < 0.001$*
1st (poorest)	3.7 (1.9; 6.9)	18.4 (15.8; 21.1)	34.6 (31.3; 37.9)
2nd	6.0 (3.8; 9.3)	22.3 (19.4; 25.1)	42.8 (39.4; 46.2)
3rd	8.1 (5.1; 12.6)	27.3 (24.2; 30.4)	42.9 (39.5; 46.3)
4th	8.1 (5.1; 12.6)	30.0 (26.9; 33.1)	45.7 (42.3; 49.1)
5th (wealthiest)	11.4 (7.8; 16.3)	34.9 (31.6; 38.1)	57.2 (53.8; 60.6)
Maternal skin colour	$P = 0.731$**	$P = 0.510$**	$P = 0.055$**
White	7.6 (6.1; 9.5)	27.0 (25.4; 28.6)	45.8 (44.0; 47.6)
Brown	5.8 (2.0; 15.5)	26.2 (21.0; 31.3)	40.6 (36.4; 44.7)
Black	6.3 (3.7; 10.5)	25.0 (21.9; 27.9)	43.0 (39.1; 46.9)
Child's sex	$P = 0.922$**	$P = 0.144$**	$P = 0.020$**
Male	7.4 (5.5; 9.8)	25.6 (23.7; 27.4)	42.9 (40.7; 45.0)
Female	7.2 (5.4; 9.5)	27.6 (25.6; 29.5)	46.5 (44.3; 48.7)
All	7.3 (5.8; 8.8)	26.5 (25.2; 27.9)	44.7 (43.2; 46.2)

[a]For trends over time, all *P*-values are <0.001; *x^2 test for trend; **x^2 test.

zero and results for that cohort are not presented. The prevalence increased for all income, maternal skin colour and child sex categories over the past two decades (Table 1). In the three cohorts, exclusive breastfeeding was associated with income, reaching more than half (57.2%) of infants from the wealthiest quintile in the 2015 cohort. Differences according to maternal skin colour or sex of the child were not marked.

For exclusive breastfeeding at 3 months of age the slope index (a measure of absolute inequalities) increased from 7.4% points in 1993 to 23.2 in 2015 (Table 2). In contrast, the concentration index (an indicator for relative inequalities) fell from 15.9 in 1993 to 8.9 in 2015, indicating that this practice is still more concentrated among the wealthiest, and that although absolute inequalities increased over time, relative inequalities fell.

The increases in prevalence of continued breastfeeding at 12 months of age were observed in all income, maternal skin colour and child sex categories over the three decades (Table 3). For instance, among infants from the poorest families, the prevalence increased from 19.2% in 1982 to 40.5%, in 2015 (*P* for linear trend <0.001) (Table 3). Statistical evidence of inverse associations with income was present in 1982 ($P < 0.001$) and in 2004 ($P = 0.018$), but over time the social gradient disappeared. In all four cohorts, prevalence of continued breastfeeding at 12 months was consistently lower among white compared with black mothers. Lastly, girls were more likely to be breastfed than boys, with differences of up to 7.1% points in 1993.

The slope index of inequality for continued breastfeeding at 12 months fell from −9.7% points in 1982 to 1.2 in 2015 (Table 2). The concentration index changed from −10.1 in 1982 to 0.2 in 2015. Both indices show that in the earlier cohorts, continued breastfeeding at 12 months was more concentrated among the poor and that the inequalities between the poorest and the wealthiest children have been completely eliminated over time.

Table 2. Slope index of inequality (SII) and concentration index (CIX) in prevalence of exclusive breastfeeding at 3 and 12 months, according to family income in quintiles

	Cohort	Slope index (SE) (%)		Concentration index (SE)	
Exclusive breastfeeding at 3 months	1993	7.4	(2.40)	15.9	(5.60)
	2004	19.8	(2.30)	12.6	(1.50)
	2015	23.2	(2.60)	8.9	(1.00)
Breastfeeding at 12 months	1982	−9.7	(1.70)	−10.1	(1.80)
	1993	−7.5	(3.50)	−6.9	(3.20)
	2004	−4.7	(2.60)	−1.8	(1.20)
	2015	1.2	(2.70)	0.2	(1.10)

SE, standard error.

Table 3. Prevalence of continued breastfeeding at 12 months according to family income, maternal skin colour and sex of the child. Pelotas 1982, 1993, 2004, and 2015

Variables	Breastfeeding at 12 months %[a] **(range)**			
	1982	1993	2004	2015
Family income (quintiles)	P <0.001*	P = 0.365*	P = 0.018*	P = 0.400*
1st (poorest)	19.2	21.9	36.3	40.5
	(16.8; 21.7)	(17.1; 27.6)	(32.9; 39.7)	(37.0; 43.9)
2nd	20.0	21.3	40.2	43.0
	(17.6; 22.4)	(16.9; 26.5)	(36.7; 43.6)	(39.6; 46.4)
3rd	13.9	21.1	39.1	39.1
	(11.9; 16.0)	(16.2; 27.1)	(35.7; 42.6)	(35.7; 42.5)
4th	12.8	19.0	38.1	40.3
	(10.8; 14.8)	(14.3; 24.8)	(44.8; 41.5)	(37.0; 43.7)
5th (wealthiest)	12.9	15.2	32.5	43.0
	(10.8; 14.9)	(11.0; 20.6)	(29.2; 35.8)	(39.6; 46.5)
Maternal skin colour	P <0.001**	P <0.001**	P <0.001**	P <0.001**
White	13.7	18.3	34.8	39.5
	(12.7; 14.7)	(15.9; 20.9)	(33.1; 36.6)	(37.7; 41.3)
Brown		13.4	37.6	41.8
	24.8	(6.8; 24.7)	(31.8; 43.4)	(37.6; 46.1)
Black	(22.0; 27.5)	29.4	46.2	48.8
		(23.5; 36.1)	(42.7; 49.7)	(44.8; 52.8)
Child's sex	P = 0.053**	P = 0.002**	P = 0.020**	P = 0 .012**
Male	14.8	16.3	35.5	39.3
	(13.4; 16.1)	(13.6; 19.6)	(33.4; 37.6)	(37.2; 41.4)
Female	16.7	23.4	39.1	43.2
	(15.3; 18.1)	(20.2; 26.9)	(36.9; 41.3)	(41.0; 45.4)
All	15.7	19.9	37.3	41.2
	(14.7; 16.7)	(17.6; 22.1)	(35.7; 38.8)	(39.7; 42.7)

[a]For trends over time, all P-values are <0.001; *x^2 test for trend; **x^2 test.

Discussion

We documented important improvements in breastfeeding practices over a 33-year period. Exclusive breastfeeding was rarely practised in 1982, but between 1993 and 2004 there was a 4-fold increase in its prevalence at 3 months of age, and between 2004 and 2015 the increase was 67%. Results from national surveys (1986, 1996, 2006 and 2013) confirmed Brazil's upward trends for exclusive breastfeeding in infants under 6 months of age and continued breastfeeding at 12 months, with the main increases observed between 1986 and 2006 (from 4.7% to 37.1% and from 25.5% to 47.4%, respectively), followed by relative stabilization in 2013 (36.6% and 45.4%, respectively).[15] The 41% prevalence of continued breastfeeding at 12 months in our 2015 cohort was similar to the 45% prevalence observed in the most recent national survey (2013). The results for exclusive breastfeeding are not comparable: we report a prevalence of 45% at the age of 3 months, whereas the national prevalence for all children aged less than 5 months in Brazil was 37%. Although Brazil experienced a recent deceleration of the gains that were observed between 1986 and 2006,[15] Pelotas continues to show an ascending trend in both exclusive and continued breastfeeding.

Brazil is internationally recognized as an exemplar country in the promotion, protection and support for breastfeeding.[16,17] Such success is the result of a series of actions carried out in the country since the establishment in the 1980s of the National Breastfeeding Program: regulation of the commercialization of infant formula and foods, introduction of the Baby Friendly Hospitals Initiative, creation of the Brazilian Network of Human Milk Banks, adoption of kangaroo mother care as public policy and implementation of the 'Feed and Breastfeed Brazil Strategy' (to promote breastfeeding and healthy complementary feeding within the universal primary health care system). These initiatives were scaled up along with media campaigns and major social mobilization events such as the World Breastfeeding Weeks and the World Human Milk Donation Days.

The Pelotas cohort studies were taking place as these initiatives were rolled out. In addition, research on the benefits of breastfeeding has been carried out in Pelotas since the 1980s[18] and the city hosted one of the participating centres in the WHO Multicentre Growth Reference Study, conducted between 1997 and 1998, which entailed the training of health professionals from the municipality public health system and provided strong support to breastfeeding delivered at households by trained nurses.[19] The increases in breastfeeding rates between 1982 and 2015 in Pelotas in part reflect the impact of this wide range of initiatives at national and local levels. This may explain why Pelotas has had a better recent track record than the rest of the country.

In terms of socioeconomic inequalities, exclusive breastfeeding was picked up by mothers in the wealthiest quintiles more rapidly than by poor mothers, and by 2015 a difference of more than 20% points had been established. This is in accordance with the inverse equity hypothesis which states that the better-off are in general the first to benefit from newly introduced interventions, due to greater access to information and quality health care.[20] The finding of an increase in absolute inequalities, expressed as a difference between rich and poor, concomitant with a decrease in relative inequalities, expressed as a ratio, is not unusual when the baseline levels among the poor were very low—only 3.7% in 1982.

It is safe to assume that in the far past, breastfeeding beyond 12 months was universal in all social groups, including the better-off who may have relied on wet nurses.[21] By 1982, continued breastfeeding was very low in the Pelotas population as a whole, but more common (19%) among the poorest than in the richest quintile (13%). This is likely a consequence of the fact that rich mothers were more likely to use formula or other types of milk than poor mothers in the middle of the 20th century, having adopted artificial feeding to a greater extent due to both marketing pressures and economic advantage. However, as the benefits of breastfeeding started to be disseminated, socioeconomic differences have virtually disappeared by 2015 due to an increase of 30% points in the richest quintile, accompanied by a smaller increase of about 20% points among mothers in the poorest quintile.

Continued breastfeeding was more common among brown and black women compared with white women, but the prevalence of exclusive breastfeeding at 3 months was similar in all groups. These results are consistent with those from a cross-sectional nationwide study conducted in 2013.[22] Some authors have argued that this finding reflects the historical practice of wet nursing, a social role played originally by slave African women who fed the infants of rich white mothers, a practice that persisted well into the 20th century[21] although it seems possible that other factors are involved as well. It is interesting to note that even though black mothers tend to be poorer than white mothers, in 2015 they had a near 10%-point lead in terms of breastfeeding at 12 months, whereas prevalence was similar in the five income quintiles.

Our results on longer duration of any breastfeeding among girls in all four cohorts, and of longer duration of exclusive breastfeeding also among girls in 2015, are consistent with previous studies from Brazil and Latin America.[23–25] Some authors have suggested that parents are more likely to think that sons have greater nutritional needs than daughters, and therefore need to receive formula and other foodstuffs at an earlier age.

The main limitation of this study is that breastfeeding information was gathered from maternal report, being subject to information bias. There are also some differences in the methodologies used to collect the breastfeeding data in the earlier cohorts. In 1982, information on breastfeeding was collected from one-third of the cohort at around

12 months of age, and the other two-thirds at around 20 months; in 1993, information was collected at 6 and 12 months. In both cohorts, mothers provided retrospective information about feeding patterns at 3 months, and the two-thirds of the 1982 cohort who were only seen at 20 months also provided retrospective information about feeding at 12 months. In 2004 and 2015, information was collected cross-sectionally at 3 and 12 months, so that there was no need for recall. It is, nevertheless, reassuring that a recent study conducted with a sample of low-income Brazilian mothers showed a strong concordance between direct observation of breastfeeding, at every 2 months during the first 2 years of life, and maternal report when children were 6 years old (intra-class correlation coefficient = 0.923; $P = 0.001$).[26] Another limitation is the fact that the 2004 and 2015 cohorts included visits to the all children at 12 months, whereas subsamples were visited in 1982 and 1993; nevertheless, even these samples included over 1300 children.

One should also note that the standard international indicator for exclusive breastfeeding includes in the denominator all children aged less than 6 months; this information is collected through surveys which include children with different ages.[27] In a cohort that is visited at specific ages, it is not possible to calculate such an indicator.

Another limitation of this study is the lack of information on water and tea intake in the 1982 cohort. At that time, there were no international recommendations regarding exclusive breastfeeding, which were only issued in the 1990s.[28] The senior authors of the present article (F.C.B. and C.G.V.) were practising physicians in Pelotas in the 1980s and attest to the fact that exclusive breastfeeding was virtually null at the time of the first cohort.

The use of data from four prospective population-based birth cohorts, with low attrition rates, represents a strength of this study. Additionally, all four cohorts were designed in a standardized manner by the same group of researchers, making the four cohorts comparable.

Our analyses confirmed that the positive trends in breastfeeding practices, which were documented for the 1982 to 2004 period,[10] persisted until 2015. However, less than half of the children in the most recent cohort were being exclusively breastfed at 3 months and received continued breastfeeding on their first birthday. In spite of the progress, the breastfeeding indicators in Pelotas are still far from the ideal. According to the World Health Organization criteria, the breastfeeding duration in the Pelotas 2015 cohort would be classified as 'poor' (median $\leq$17 months) and exclusive breastfeeding practices would be classified at best as 'fair' (12–49%).[27] Of even greater concern is that the beneficial breastfeeding practices are being more rapidly adopted by high-income than low-income women. Action is needed to speed up the improvement of appropriate breastfeeding practices, particularly among poor families which will lag behind if current trends persist.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Center, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centers of Excellence (PRONEX), Brazilian National Council for Scientific and Technological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Aluisio J D Barros,[1] Alicia Matijasevich,[2] Andrea Dâmaso Bertoldi,[1] Fernando C Wehrmeister,[1] Helen Gonçalves,[1] Joseph Murray,[1] Maria Cecilia F Assunção,[1] Mariangela F Silveira,[1] Marlos Rodrigues Domingues[1] and Pedro R C Hallal.[1]

[1]Federal University of Pelotas, Brazil and [2]University of São Paulo, Brazil.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i46–i53
doi: 10.1093/ije/dyy106
Advance Access Publication Date: 22 June 2018
Supplement Article

Supplement Article

Low birthweight and preterm birth: trends and inequalities in four population-based birth cohorts in Pelotas, Brazil, 1982–2015

Mariangela F Silveira ,[1,2]* Cesar G Victora ,[2] Bernardo L Horta ,[2] Bruna GC da Silva,[2] Alicia Matijasevich ,[2,3] Fernando C Barros[4] and the Pelotas Cohorts Study Group**

[1]Maternal and Child Health Department, Federal University of Pelotas, Pelotas, Brazil, [2]Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil, [3]Department of Preventive Medicine, Faculty of Medicine FMUSP, University of São Paulo, São Paulo, Brazil and [4]Postgraduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

*Corresponding author. Federal University of Pelotas, Marechal Deodoro, 1160, Pelotas RS 96020-220, Brazil.
E-mail: mariangelafreitassilveira@gmail.com
**Members listed at end of article.

Editorial decision 7 May 2018; Accepted 15 May 2018

Abstract

Background: Despite positive changes in most maternal risk factors in Brazil, previous studies did not show reductions in preterm birth and low birthweight. We analysed trends and inequalities in these outcomes over a 33-year period in a Brazilian city.

Methods: Four population-based birth cohort studies were carried out in the city of Pelotas in 1982, 1993, 2004 and 2015, with samples ranging from 4231 to 5914 liveborn children. Low birthweight (LBW) was defined as <2500 g, and preterm birth as less than 37 weeks of gestation. Information was collected on family income, maternal skin colour and other risk factors for low birthweight. Multivariable linear regression was used to estimate the contribution of risk factors to time trends in birthweight.

Results: Preterm births increased from 5.8% (1982) to 13.8% (2015), and LBW prevalence increased from 9.0% to 10.1%, being higher for boys and for children born to mothers with low income and brown or black skin colour. Mean birthweight remained stable, around 3200 g, but increased from 3058 to 3146 g in the poorest quintile and decreased from 3307 to 3227 g in the richest quintile. After adjustment for risk factors for LBW, mean birthweight was estimated to have declined by 160 g over 1982–2015 (reductions of 103 g in the poorest and 213 g in the richest quintiles).

Conclusions: Data from four birth cohorts show that preterm births increased markedly. Mean birthweights remained stable over a 33-year period. Increased prevalence of preterm and early term births, associated with high levels of obstetric interventions, has offset the expected improvements due to reduction in risk factors for low birthweight.

Key words: Infant, low birthweight, premature birth, cohort studies, birthweights, preterm births

Key Messages

- At the population level, mean birthweight remained stable from 1982 to 2015, as did low birthweight.
- Preterm birth prevalence increased markedly, despite changes in methods of ascertainment over time.
- The stability in mean birthweight resulted from a combination of increases among children born to women in the poorest quintiles and declines in the richest quintiles.
- The prevalences of most risk factors for low birthweight were markedly reduced over time; after adjustment for these factors, it is estimated that mean birthweight declined by 160 g from 1982 to 2015.
- The most likely explanation for these results is the extremely high prevalence of caesarean section, particularly among rich women, with a resulting increase in preterm and early term deliveries due to schedule deliveries.

Introduction

Preterm birth and low birthweight are major risks factor for neonatal, infant and under-five mortality. Globally, 16% of all children are born with low birthweight (LBW, <2500 g),[1] and 11.1% are born preterm (less than 37 completed weeks of gestation).[2] In Brazil, data from the National Live Births System (SINASC) which covers 96% of all births in the country, show a prevalence of preterm birth of 11.4% in 2016.[3] Although several countries fail to report on birthweight, it is estimated that 9% of Latin American newborns fall in this category.[1]

LBW may result from preterm delivery, intrauterine growth restriction or a combination of both. A systematic review found that each of these conditions contributes to approximately half of all LBW babies.[4] In 2010, preterm births (PTB) were estimated to account for 11% of all live births in the world.[2] PTB complications are the leading cause of death among children under 5 years of age, being responsible for approximately 1 million deaths in 2015.[5] PTB is also associated with long-term consequences including cerebral palsy, sensory deficits, learning disabilities and respiratory illnesses, compared with term birth.[2]

Fetal or intrauterine growth restriction (IUGR, defined as a birthweight below the 10th centile of a reference population) was estimated to affect 19.3% of all babies born in low- and middle-income countries in 2012.[6] IUGR is associated with a near 2-fold increase in the risk of neonatal and post neonatal mortality among term infants; the risk is markedly higher for newborns who present both IURG and PTB.[7] IUGR is also a major contributor to child undernutrition and to poor psychomotor development.[7]

In 2008, we reported on trends in birthweight and preterm births in three population-based birth cohorts in the city of Pelotas in 1982, 1993 and 2004.[8] We now extend this time-series to incorporate the 2015 birth cohort. Our objectives were to report on time trends in preterm births, LBW and mean birthweight, and to assess inequalities in birthweight according to family income, maternal skin colour and sex of the child.

Methods

Over the course of the years of 1982, 1993, 2004 and 2015, all hospital births in the city of Pelotas were identified through daily visits to all maternity wards, and mothers who lived in the urban area were invited to join the studies. Those who accepted were interviewed by the study team using a structured questionnaire, and anthropometric data were obtained from the women and their newborns. Methodological details of each cohort (1982, 1993, 2004 and 2015) are provided elsewhere.[9–12]

Newborns were weighed within 24 h of birth, using paediatric scales with a precision of 10 g, in each participating hospital. LBW was defined as a birthweight below 2 500 g.[13]

The method of assessment of gestational age changed over time. In 1982 and 1993 it was based on the date of the last menstrual period (LMP) provided by the mother, and unknown and unreliable cases were excluded. These represented 21.0% and 10.2% of all newborns, respectively. In 2004 and 2015, we adopted the best obstetric estimate based primarily on first- or second-trimester ultrasound when available. When ultrasound was not available, the estimate was based on the LMP. For the 2004 and 2015 cohorts, we also present estimates based solely on the LMP for comparability with the earlier cohorts.

Mothers were interviewed during the hospital stay and provided information on monthly family income, calculated from the sum of incomes of family members, and divided into quintiles. As noted in a previous publication,[14] income data for 1993 are less reliable than for the other cohorts, due to hyperinflation during that year. Information was also collected on maternal skin colour, categorized as white, black or other by the interviewer, except in 2015

Table 1. Distribution of birthweight among live births, Pelotas, Southern Brazil, 1982, 1993, 2004 and 2015

Birthweight (g)	1982		1993		2004		2015	
	n	%	*n*	%	*n*	%	*n*	%
<1000	17	0.3	11	0.2	24	0.6	15	0.4
1000–1499	40	0.8	24	0.5	29	0.7	24	0.6
1500–1999	92	1.6	82	1.6	70	1.7	56	1.4
2000–2499	329	5.7	351	6.8	249	6.0	250	6.0
2500–2999	1361	23.4	1283	24.9	1016	24.5	960	23.1
3000–3499	2211	38.1	2040	39.6	1648	39.8	1713	41.3
3500–3999	1416	24.4	1080	21.0	912	22.0	919	22.1
≥4000	345	5.9	280	5.4	198	4.8	214	5.2
Not weighed	5		17		1		13	
<2500	8.2		9.1		9.0		8.3	
Mean birthweight in g (SD)	3201 (554)		3169 (539)		3167 (554)		3198 (537)	
Gestational age (weeks)								
<37	265	5.8	517	11.2	567	13.7	576	13.8
37–38	1007	21.9	906	19.7	1244	30.0	1562	37.5
39–41	2854	62.1	2661	57.8	2064	49.8	1996	47.9
42+	469	10.2	518	11.3	267	6.4	30	0.7
Number of children	5816		5168		4147		4164	

when it was self-reported; in 1982, only two categories (white or other) were recorded.

For the multivariable analyses, information was also collected on known risk factors for birthweight which were measured in the four cohorts, including maternal age (<20, 20–24, 25–29, 30–34, >=35 years), schooling (<4, 5–8, 9–11 or >=12 years), height (<150, 150–159, 160–169, >=170 cm), pre-pregnancy body mass index (<18.5, 18.5–24.9, 25.0–29.0, >= 30.0 kg/m^2), smoking during pregnancy (yes, no), parity (0, 1, >=2 children), preceding birth interval (<24 months, >=24 months, primipara), antenatal care (<4, 4–7, >=8 visits) and marital status (married or in union, other). In the multivariable analyses, income was measured in minimum wages at the time of each cohort, and coded as <=1.0, 1.1–3.0, 3.1–6.0, 6.1–10.0 and >10. Details on the instruments used to collect these variables are available in other articles in this issue.[14–16] Maternal reports of diabetes and hypertension during pregnancy were included in the multivariable analyses.

For family income expressed in quintiles, the slope index of inequality (SII) and concentration index (CIX) were calculated to assess absolute and relative inequalities. The SII can be interpreted as the difference, in percentage points, between prevalence at the top and at the bottom of the income scale; it ranges from -100% to 100% points. The concentration index is a measure similar to the Gini coefficient; a value of zero indicates perfect equality, whereas negative values indicate higher prevalence of the outcome among the poor.[17,18]

All analyses were restricted to live, singleton newborns.[13] The chi-square test was used to compare the distribution of maternal characteristics in the four cohorts and trends over time; when applicable the chi-square statistic for linear trend was also calculated. Multivariable linear regression was used to estimate the magnitude of the changes in mean birthweight over time, taking into account changes in the risk factors listed above. All analyses were performed using the Stata 13.1 software.[19]

Ethical approval for studies was not required in Brazil until 1996. The 2004 and 2015 studies were each approved by the Ethics Committee of the School of Medicine and School of Physical Education, Federal University of Pelotas, and written consent was obtained from the mothers.

Results

The numbers of liveborn singletons in the four cohorts were 5816, 5168, 4147 and 4164. Birthweight information was missing for 5 (0.09%), 17 (0.33%), 1 (0.02%) and 13 (0.31%) children, respectively.

Table 1 shows the distribution of birthweight and gestational age in the four cohorts. Preterm births increased markedly from 5.8% in 1982 to 13.8% in 2015; the prevalence of early term births (37–38 weeks' gestation) also increased from 21.9% in 1982 to 37.5% in 2015, Conversely, full-term births (39–41 weeks) decreased substantially in the period, from 62.1% to 47.9%.

Table 2. Prevalence (95% CI) of low birthweight according to sex of the newborn, quintiles of family income, maternal schooling and maternal skin colour, Pelotas, Southern Brazil, 1982, 1993, 2004 and 2015

Variable	Percent low birthweight by birth cohort				P (χ^2 linear trend)
	1982	1993	2004	2015	
Sex	$P = 0.003$	$P = 0.005$	$P = 0.044$	$P = 0.089$	
Male	7.2 (6.3; 8.1)	8.0 (6.9; 9.0)	8.1 (7.0; 9.3)	7.6 (6.5; 8.7)	0.476
Female	9.3 (8.2; 10.4)	10.2 (9.1; 11.4)	9.9 (8.6; 11.2)	9.1 (7.8; 10.3)	0.784
Family income quintiles	$P < 0.001$	$P = 0.001$	$P < 0.001$	$P = 0.002$	
Q1	13.5 (11.5; 15.4)	10.4 (8.5; 12.3)	13.1 (10.8; 15.4)	11.7 (9.5; 13.9)	0.505
Q2	8.6 (7.0; 10.2)	10.4 (8.6; 12.1)	10.5 (10.8; 15.4)	8.0 (6.1; 9.8)	0.806
Q3	6.9 (5.4; 8.3)	9.1 (7.2; 11.0)	6.6 (4.9; 8.3)	6.8 (5.1; 8.6)	0.640
Q4	6.6 (5.1; 8.0)	9.0 (7.3; 10.8)	7.5 (5.7; 9.2)	8.4 (6.5; 10.2)	0.257
Q5	5.7 (4.4; 7.0)	6.4 (4.9; 7.9)	7.0 (5.3; 8.8)	6.7 (5.0; 8.4)	0.273
Maternal skin colour[a]	$P = 0.007$	$P = 0.034$	$P = 0.053$	$P = 0.595$	
White	7.8 (7.0; 8.5)	8.6 (7.8; 9.5)	8.5 (7.5; 9.4)	8.5 (7.5; 9.5)	0.290
Brown	10.3 (8.5; 12.1)	10.0 (6.1; 13.9)	8.7 (5.4; 11.9)	7.7 (5.4; 9.9)	0.058
Black		10.8 (8.8; 12.8)	11.0 (8.9; 13.1)	8.2 (6.1; 10.4)	

[a]The test for linear trend according to maternal skin colour compares white-skinned mothers against black- or brown-skinned mothers, given that in 1982 the information was collected for two categories.

For consistency, we reanalysed the data from the four cohorts using only the date of the LMP to assess gestational age, instead of also using ultrasound results in the two more recent cohorts. The resulting prevalences of preterm birth were 5.8%, 11.2%, 16.2% and 17.7% in 1982, 1993, 2004 and 2015, respectively. The corresponding prevalences of early term births were 21.9%, 19.7%, 27.6% and 33.0%.

The distribution of birthweights was remarkably similar in the four cohorts, as was the case for the mean and standard deviation values. The proportion of newborns with low birthweight remained stable at around 8% to 9% throughout the period (P for trend = 0.80). Mean birthweight also remained stable at around 3.2 kg (P for trend = 0.47)

As the sources of information on gestational age varied over time, with many missing cases in 1982 and 1993, analyses of socioeconomic and skin colour inequalities are only presented for birthweight. Table 2 shows LBW prevalence according to sex, income and maternal skin colour. As expected due to the use of the same absolute cutoff for both sexes, prevalence was higher among girls than boys in the four cohorts. There was no evidence of a time trend in low birthweight for either sex. In all cohorts, LBW was most frequent in the poorest income quintile and lowest in the richest quintile, except for 2004 when prevalence in the third quintile was slightly lower than in the richest quintile. Regarding maternal skin colour, prevalence was lowest for children born to white mothers, except in 2015 when there was no statistical evidence of a difference.

The magnitude of absolute income-related inequalities was summarized by the slope index, which was equal to -8.7% points [standard error (SE) 1.3] in 1982, -4.5 (SE 1.4) in 1993, -7.6 (SE 1.6) in 2004 and -4.7 (SE 1.6) in 2015. The concentration indices for relative inequalities were equal to -16.3 (SE 2.5) in 1982, -8.9 (SE 2.5) in 1993, -13.3 (SE 3.0) in 2004 and -9.5 (SE 3.0) in 2015. Both indices show that inequalities remained unchanged during the study period.

Similar analyses for mean birthweight are shown in Table 3. Boys were about 100 g heavier than girls in all cohorts. Mean birthweight increased by 88 g among the poorest quintile (P for trend 0.004) and decreased by 57 g ($P = 0.049$) in the fourth and by 80 g ($P < 0.001$) in the richest quintile. The mean difference between the richest and poorest quintile fell from 249 g in 1982 to 81 g in 2015. Regarding maternal skin colour, mean birthweight remained stable for children born to white mothers, but increased by about 60 g (P = 0.01) for those born to black and brown-skinned women.

Because there were important changes in the distribution of risk and protective factors associated with birthweight (Table 4), we used multivariable linear regression to estimate the likely changes in birthweight over time, had the distribution of these factors remained constant (Table 5). In the first analyses, we adjusted for all factors in Table 4 except for diabetes and hypertension. Whereas in the unadjusted analyses mean birthweight in 2015 was only 4 g lower than in 1982, after adjustment for changes in risk factors, mean birthweight became 160 g lower in 2015 than in 1982. The effects of adjustment were larger for the richest (-213 g) than for the poorest quintile (-103 g). Further adjustment for reports of diabetes and hypertension changed the overall estimate of the reduction in birthweight over time from 160 g to 153 g [95% confidence interval (CI) 128–177].

Table 3. Mean (95% CI) birthweight in grams according to sex of the newborn, quintiles of family income and maternal skin colour. Pelotas, Southern Brazil, 1982, 1993, 2004, and 2015

Variable	Mean birthweight (g) by birth cohort				*P* (linear trend)
	1982	1993	2004	2015	
Sex	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	
Male	3261 (3241; 3281)	3235 (3213; 3256)	3216 (3192; 3240)	3260 (3237; 3284)	0.509
Female	3139 (3120; 3159)	3104 (3084; 3124)	3113 (3090; 3137)	3133 (3111; 3156)	0.687
Family income	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P = 0.006$	
Q1	3058 (3027; 3090)	3113 (3080; 3147)	3078 (3038; 3117)	3146 (3108; 3185)	0.004
Q2	3164 (3131; 3196)	3136 (3105; 3167)	3116 (3076; 3156)	3198 (3160; 3235)	0.428
Q3	3222 (3191; 3254)	3144 (3109; 3180)	3186 (3150; 3222)	3219 (3183; 3255)	0.996
Q4	3256 (3225; 3286)	3208 (3174; 3243)	3233 (3198; 3269)	3199 (3164; 3235)	0.049
Q5	3307 (3276; 3338)	3255 (3224; 3287)	3224 (3187; 3260)	3227 (3191; 3262)	<0.001
Maternal skin colour[a]	$P < 0.001$	$P < 0.001$	$P = 0.001$	$P = 0.523$	
White	3216 (3200; 3232)	3189 (3172; 3205)	3184 (3165; 3203)	3201 (3182; 3221)	0.122
Brown	3135 (3100; 3169)	3077 (3010; 3143)	3160 (3102; 3218)	3184 (3141; 3227)	0.010
Black		3108 (3071; 3144)	3107 (3065; 3148)	3194 (3153; 3234)	

[a]The test for linear trend according to maternal skin colour compares white-skinned mothers against black- or brown-skinned mothers, given that in 1982 the information was collected for two categories.

Table 4. Evolution of risk and protective factors for low birthweight, 1982–2015

	Cohort			
	1982	1993	2004	2015
Family income <1 minimum wage	21.7%	18.5%	21.0%	12.7%
Not in marriage or union	8.2%	12.4%	16.4%	14.2%
Black or brown skin colour	17.9%	22.6%	26.9%	28.2%
Maternal age >= 35 years	9.8%	10.9%	13.3%	14.5%
Schooling <4 years	33.0%	27.9%	15.4%	9.2%
Maternal height <150 cm	10.9%	4.5%	6.9%	2.5%
BMI <18.5 kg/m^2	6.6%	8.6%	5.0%	3.7%
BMI >= 30 kg/m^2	3.7%	4.6%	6.1%	18.4%
Smoking during pregnancy	35.6%	33.2%	27.6%	16.6%
Primiparity	39.6%	35.3%	39.7%	49.4%
Parity 2 or greater	16.1%	19.4%	18.3%	8.5%
Birth interval <24 months	18.8%	11.2%	8.6%	5.8%
Antenatal care <4 visits	15.8%	11.6%	6.9%	5.6%
Report of gestational diabetes[a]	0.3%	2.8%	2.9%	8.6%
Report of hypertension in pregnancy[a]	5.3%	15.7%	23.7%	25.2%

[a]Due to changes in diagnostic criteria and in data collection methods, and to lower number of antenatal care visits for diagnosis of these conditions, the prevalence of diabetes and hypertension in the earlier cohorts was likely underestimated.

Discussion

Our results show that preterm and early term births increased markedly over a 33-year period in the Brazilian city of Pelotas. For gestational age, changes over time are affected by differences in the methods of assessment of gestational age, and the high proportion of missing cases in 1982 and 1993 when only the date of the last menstrual period was used. Missing data were more common among less educated and poorer mothers, and thus the prevalence of preterm births was likely underestimated in the early cohorts. With increased use of ultrasound during pregnancy, our methods of gestational age assessment changed in the 2004 and 2015 cohorts. In the latter, 84.4% of all newborns had ultrasound results during the first or second trimester recorded in their mother's antenatal cards, and the prevalence of preterm birth for these gestations was 13.8%. During the postpartum interview, 90.7% of the mothers provided information on the date of the last menstrual period, and the prevalence of preterm birth was 18.9%. Even if prevalence for gestations with missing data was twice as high for gestations with existing information as those with data, the corrected prevalence would be 7.0% in 1982 and 12.4% in 1993, which are lower values than for the more recent cohorts. The rise in preterm births was even more marked when we analysed the four cohorts using LMP data. Therefore, in spite of different methods being used in each study, there is strong evidence of an increase in preterm deliveries in Pelotas.

The increased preterm prevalence had been described in our earlier publication[8] and is consistent with other Brazilian studies. A systematic review of peer-reviewed literature showed rising trends from the 1990s onwards, particularly in the southeastern and southern regions where Pelotas is located.[20] In the Ribeirão Preto cohorts, preterm births increased from 7.5% in 1978–79 to 12.8% in 2004.[21] Overmedicalization of childbirth, and in particular the sharp increase in cesarean sections, have been blamed for the current epidemic of preterm deliveries in Brazil.[22–25]

Table 5. Multivariable linear regression analyses showing differences in mean birthweight in the four cohorts with adjustment for changes over time in risk and protective factors[a]

		1982	1993	2004	2015
Unadjusted	Mean (g)	3201	3169	3166	3198
	Estimate	0 (reference)	−32	−35	−4
	95% CI		(−53; −12)	(−56; −13)	(−25; 18)
Fully adjusted (all births)	Estimate	0 (reference)	−107	−112	−160
	95% CI		(−87; −128)	(−90; −135)	(−136; −184)
Fully adjusted (poorest quintile)	Estimate	0 (reference)	−54	−84	−103
	95% CI		(−101; −7)	(−136; −32)	(−163; −44)
Fully adjusted (richest quintile)	Estimate	0 (reference)	−128	−147	−213
	95% CI		(−175; −80)	(−197; −97)	(−265; −161)

[a]Adjusted for family income in minimum wages, maternal skin colour, age, schooling, marital status, height, body mass index, smoking, parity, birth interval and antenatal care.

In Pelotas, cesarean sections increased from 27.7% to 65.1% of all deliveries from 1982 to 2015, when it accounted for 86.6% of all births in the richest quintile.[26] Many caesarean sections are scheduled, typically when gestational ages are estimated to reach 38 weeks. Each week of gestational age from 37 to 40 weeks is associated with average gains of 150 g for girls and of 170 g for boys, so that even minor shifts could lead to the effect observed among wealthy women.[27]

One important finding of our study is that—for the whole population—mean birthweight and LBW prevalence remained stable. The only other Brazilian study spanning several decades was carried out in the southeastern city of Ribeirão Preto and showed an increase in LBW from 7.2% to 10.7% from 1978–79 to 1994.[21] More recent time-series based on the National Live Birth Registration System showed a slight increase in national low birthweight prevalence from 7.9% in 1995 to 8.4% in 2015.[24] It is paradoxical to find that the highest prevalences of low birthweight are found in the most developed regions of the country (the south and southeast), compared with the poorer regions (the northeast and north). It is postulated that this paradox is explained by excessive cesarean sections in the richest areas.[28,29]

Our results are compatible with other Brazilian studies. Prevalence of low birthweight in Latin America is estimated at 9%, with 7% in Argentina and 8% in Uruguay, countries that are closest to Pelotas.[1]

Brazilian studies on LBW suggest that the main risk factors include low family income, low education, black or brown skin colour, young maternal age, short stature, low pre-pregnancy weight, primiparity, short birth intervals, lack of prenatal care and maternal smoking during pregnancy.[30–33] Nearly all of these risk factors evolved favourably in Pelotas from 1982 to 2015 (Table 4).[14–16,26] Women became more educated, taller and less likely to smoke or to present with underweight (low body mass index). There are now fewer adolescent mothers, parity is lower and birth intervals longer. The number of antenatal care visits increased substantially. In light of all such changes, one would expect the prevalence of low birthweight to be reduced, and mean birthweight to increase. When we accounted for changes in risk factors over time, mean birthweight in 2015 became 160 g lower than in 1982. The difference was more marked for women in the richest quintile (213g) than in the poorest quintile (103 g). We also ran a model with the above-mentioned covariates plus maternal reports of diabetes and hypertension, for which the time-series (Table 4) was likely affected by changes in diagnostic criteria[34] and by increased use of antenatal care with greater opportunity for diagnosis. As in the previous analyses, the mean birthweight in 2015 was substantially lower than would be expected (152 g on average) given the changes in risk and protective factors over time.

The findings from this regression analysis support the hypothesis that obstetric interventions, which increased over time and are particularly frequent among high-income women, may explain why birthweights failed to increase in accordance with the reduction in the prevalence of risk factors. A simple comparison of birthweights in vaginal and cesarean deliveries is not useful, because the latter include a mixture of procedures with medical indications (associated with lower birthweights due to morbidity) and those without medical indications (which would primarily affect women of high socioeconomic position whose newborns should present higher birthweights). We do not have comparable data on reasons for caesarean sections in the four cohorts, and in addition there are indications that obstetricians may often report medical indications for purely elective procedures; for these reasons, it was not possible to separate these two categories of caesarean sections and assess their specific associations with birthweights.

Time trends in low birthweight prevalence according to income groups were not as clear-cut as for mean birthweight, which suggests that the main impact of caesarean sections has been on babies born weighing 2500 g or more. This is consistent with the marked increase in the prevalence of early term deliveries at 37–38 weeks, from 22.3% in 1982 to 37.1% in 2015, which must have had a negative impact on mean birthweight. The hypothesis is also supported by the actual decline in mean birthweight among children born to wealthy women (Table 3), accompanied by an increase among those born to poor women, among whom the prevalence of caesarean sections is much lower.

During the 33-year period covered by our cohorts, there have been substantial improvements in maternal and child health in Brazil as a whole,[25] which are reflected in the data from Pelotas. These positive changes, however, were not reflected in the distribution of birthweights, which remained stable in spite of marked reductions in the prevalence of its main known risk factors. The extremely high rates of caesarean sections may be held accountable for the lack of progress.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Centre, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centres of Excellence (PRONEX), Brazilian National Council for Scientific and Technological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child, and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Aluisio J D Barros,[1] Ana M B Menezes,[1] Andrea Dâmaso Bertoldi,[1] Diego G Bassani,[2] Fernando C Wehrmeister,[1] Helen Gonçalves,[1] Iná S Santos,[1] Joseph Murray,[1] Luciana Tovo-Rodrigues,[1] Maria Cecilia F Assunção,[1] Marlos Rodrigues Domingues[1] and Pedro R C Hallal[1]

[1]Federal University of Pelotas, Brazil and [2]University of Toronto, Canada.

Conflict of interest: None declared.

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International Journal of Epidemiology, 2019, i63–i71
doi: 10.1093/ije/dyy228
Supplement Article

Supplement Article

Hospital admissions in the first year of life: inequalities over three decades in a southern Brazilian city

Fernando C Wehrmeister ,[1]* Cesar G Victora ,[1] Bernardo L Horta ,[1] Ana M B Menezes ,[1] Iná S Santos,[1] Andréa Dâmaso Bertoldi ,[1] Bruna G C da Silva ,[1] Fernando C Barros [2] and the Pelotas Cohorts Study Group**

[1]Postgraduate Program in Epidemiology, Federal University of Pelotas, Pelotas, Brazil and [2]Postgraduate Program in Health and Behavior, Catholic University of Pelotas, Pelotas, Brazil

*Corresponding author. Postgraduate Program in Epidemiology, Federal University of Pelotas, R. Mal. Deodoro 1160 3o. piso, 96020-220 Pelotas, RS, Brazil. E-mail: fcwehrmeister@gmail.com
**Members listed at end of article.

Editorial decision 13 September 2018; Accepted 8 October 2018

Abstract

Background: Hospital admissions in infancy are declining in several countries. We describe admissions to neonatal intensive care units (NICU) and other hospitalizations over a 33-year period in the Brazilian city of Pelotas.
Methods: We analysed data from four population-based birth cohorts launched in 1982, 1993, 2004 and 2015, each including all hospital births in the calendar year. NICU and other hospital admissions during infancy were reported by the mothers in the perinatal interview and at the 12-month visit, respectively. We describe these outcomes by sex of the child, family income and maternal skin colour.
Results: In 1982, NICUs did not exist in the city; admissions into NICUs increased from 2.7% of all newborns in 1993 to 6.7% in 2015, and admission rates were similar in all income groups. Hospitalizations during the first year of life fell by 29%, from 23.7% in 1982 to 16.8% in 2015, and diarrhoea admissions fell by 95.2%. Pneumonia admissions fell by 46.3% from 1993 to 2015 (no data available for 1982). Admissions due to perinatal causes increased during the period. In the poorest income quintile, total admissions fell by 33% (from 35.7% to 23.9%), but in the richest quintile these remained stable at around 10%, leading to a reduction in inequalities. Over the whole period, children born to women with black or brown skin were 30% more likely to be admitted than those of white-skinned mothers.
Conclusions: Whereas NICU admissions increased, total admissions in the first year of life declined by nearly one-third. Socioeconomic disparities were reduced, but important gaps remain.

Key words: Child health, hospitalization, health care disparities, socioeconomic factors, cohort studies

Key Messages

- Hospital admissions in the first year of life fell from 23% of all infants in 1982 to 16.8% in 2015.
- The decline was particularly steep for diarrhoea admissions, which fell from being the leading cause of admissions in 1982 to virtual disappearance by 2015.
- Admissions due to complications of prematurity increased over time, as measured by NICU admissions (from 2.7% of all newborns in 1993 to 6.7% in 2015), as did admissions during the first year of life due to perinatal causes.
- NICU admissions were not related to family income or maternal skin colour.
- Income-related inequalities in admissions were reduced over time, but remained important up to 2015 with a 2-fold excess in the poorest compared with the richest quintiles.
- Over the whole period, children born to Black or Brown mothers were 30% more likely to be hospitalized in infancy than children of White mothers.

Introduction

Hospital admissions are an important public health issue worldwide, with high costs for health systems, individuals and society. Infants and the elderly are the age groups at highest risk of hospitalization. In high-income countries, the risk of admission during the first year currently ranges widely, from 4.4%[1] in New York to 31% in Australia.[2] Some studies suggest declining trends in hospital admissions for infants, as was the case in New South Wales[3] where the rate decreased by 1.8% per year from 2001 to 2009.

In Brazil, data from the National Information System indicates that hospitalization in the first year of life decreased from 24.4 in 1998 to 19.0 in 2015 per 100 live births.[4] In 1998, the major causes of hospitalizations were related to respiratory disease (34%), followed by perinatal conditions (14%) and other infectious diseases (22%), whereas in 2017 this picture changed: 46% of hospital admission were due to perinatal conditions, 24% due to respiratory diseases and only 11% due to other infectious diseases.[4]

Regarding inequalities in hospital admission, children living in urban settings are at high risk of hospitalization compared with those who live in rural areas.[5] Also, socially deprived ethnic groups[1,6,7] are at greater risk of hospital admission, the same occurring with emergency hospital admissions.[8]

Time trends in hospital admissions in the Pelotas (Brazil) 1982, 1993 and 2004 birth cohorts were reported in 2008.[9] In this report, we extend this time series to also include the 2015 cohort, covering a period of three decades, and assess admissions to neonatal intensive care units (NICU). Our analyses report levels and trends in inequalities associated with family income, child sex and maternal skin colour.

Methods

All live births occurring in the city of Pelotas, Brazil, during the calendar years of 1982, 1993, 2004 and 2015 were included in each cohort study. From 1 January to 31 December 31 each year, all urban women delivering in the city's hospitals were invited to participate. The four cohorts included 5914, 5249, 4231 and 4275 live births, respectively.[10]

NICU admissions were based on maternal report at the perinatal interview that took place soon after delivery. All infants referred to an NICU were included in the analysis, irrespective of the duration of hospitalization. This information was not collected in 1982, when NICUs were not yet available in the city.

In the first cohort, information on hospital admissions was collected in early 1983 when children born from January to April 1982 were sought at home, and their mothers interviewed. Because the most frequent cause for admission was diarrhoea, information on cause was only collected for this condition, and all other causes were grouped together. A validation study comparing the responses of 120 mothers with hospital charts showed that the underlying cause of hospitalization had been correctly provided by the mother in 90% of cases.[11]

For the 1993 birth cohort, all babies born weighing less than 2500 g, and a random sample of 20% of all other children, were sought at the age of 12 months. On this occasion, mothers were asked about hospitalizations and their causes.

In addition, a detailed study of hospital admissions was conducted in this cohort. The four city hospitals with paediatric wards were visited on a weekly basis during 1993 and 1994 to identify admissions of cohort members. Two independent reviewers analysed the available information and determined the cause of hospitalization according to the ninth International Classification of Diseases (ICD-9). In case of disagreement, a senior referee took the final decision. Information was available for over 98% of hospitalizations of infants during this period.[12] Weighted data analyses were carried out to account for the oversampling of low-birthweight infants in 1993.

In 2004 and 2015, an attempt was made to locate all cohort members at the age of 12 months. Information on hospitalizations and causes was collected from the mothers, and the variables were recorded in a similar way as in the 1993 birth cohort.

Hospitalizations were defined as inpatient admissions lasting more than 24 h. In all cohorts, all-cause and diarrhoea admissions were recorded. From 1993 to 2015, information was also recorded on pneumonia admissions and on perinatal causes. The latter were recorded when a perinatal condition was reported (e.g. prematurity or neonatal sepsis), or when the baby was hospitalized during the first month of life due to causes other than diarrhoea or pneumonia. Among all children who were hospitalized in the four cohorts, 26% were admitted more than once. Therefore, the total number of children admitted to hospital does not correspond to the sum of the groups of causes. All analyses were repeated considering only the first admission per child.

The frequencies of NICU and hospital admissions were analysed according to child sex (male/female), family income (number of monthly minimum wages received by the family, divided in quintiles) and maternal skin colour (white, brown and black, observed by the interviewer in 1982 and 1993 and self-reported in 2004 and 2015). For family income, we also calculated the slope index of inequality (SII) for absolute inequality and the concentration index (CIX) for relative inequality. The SII is a measure based on the difference in the values of a given outcome between the extremes of the distribution, through a logistic regression for binary outcomes.[13] It is expressed in percentage points ranging from −100 and 100, with the zero representing no inequality, and negative values are translated as the poorest group having high prevalence of the outcome. The CIX is a relative inequality measure similar measure to the Gini index, and uses the concentration of a given outcome according to socioeconomic status.[13] It is also expressed in a range from −100 to 100, however with no defined unit. The interpretation is similar to the SII. For sex and maternal skin colour, we calculated the absolute (arithmetical difference) and relative (ratio) inequalities for male/female and Black/White, respectively.

We used the statistical software Stata, version 13.[14] We calculated the bivariate association in each cohort using the chi square test for heterogeneity for the variables sex and skin colour, and for linear trend in the case of income quintiles. To analyse changes over time, we used the chi square test for trend. Interactions between exposures and cohort year were tested through Poisson regression. In the presence of interaction, we presented the results separately for each cohort. In the absence of interaction, pooled results were presented.

The protocols of each phase in each cohort were approved by the Institutional Review Board of the Federal University of Pelotas. In the years 1982 and 1993, a verbal consent from the mothers was obtained. In 2004 and 2015, a consent form was filled and signed by the mothers who were fully informed and accepted participation in the study.

Results

The numbers of children in the analyses were 1462 in 1982 (subsample), 1363 in 1993 (subsample), 3907 in 2004 and 4015 in 2015, corresponding to response rates of 79.5%, 93.4%, 94.4% and 95.4%, respectively, of eligible children.

NICU admission increased from 2.7% in 1993 to 6.7% in 2015. The frequency of hospitalizations due to any cause decreased from 23.7% in 1982 to 18.1% in 1993, and remained nearly stable until 2015, when it reached 16.8% (Table 1). Important reductions in hospital admissions due to diarrhoea and pneumonia were observed over time. The prevalence of hospitalizations due to perinatal causes (not available in 1982) was 2.0% in 1993, 7.0% in 1993 and 5.1% in 2015. The mean number of hospitalizations per child ranged from zero to six. The average number decreased from 0.4 [standard deviation (SD) = 0.8] to 0.2 (SD = 0.7) over the three decades (Table 1).

Table 2 shows NICU admissions in the three more recent birth cohorts, analysed by the child's sex, family income quintiles and maternal skin colour. Admissions increased over time in all subgroups and was slightly higher for male babies compared with females, especially in 2015. Regarding income groups, there was little statistical evidence of inequality in any of the cohorts, with the 95% confidence intervals for the slope and concentration indices including the null value. There was no interaction ($p = 0.544$) between family income and cohort in NICU admissions. In relation to maternal skin colour, babies born to Black mothers were more likely to be admitted than those with White mothers in 1993, but there was no evidence of a difference in 2015 (p-value for interaction = 0.010).

Table 1. Percentages of cohort children admitted to NICUs and of hospital admissions in the first year of life, according to cause

Admission and cause	Birth cohort				*P*-value*
	1982	1993	2004	2015	
NICU admission	0	2.7 (1.9 to 3.4)	5.1 (4.5 to 5.8)	6.7 (5.9 to 7.5)	<0.001
Diarrhoea	6.3 (5.0 to 7.5)	2.4 (1.5 to 3.3)	1.0 (0.7 to 1.3)	0.3 (0.2 to 0.5)	<0.001
Pneumonia	–	6.5 (5.1 to 7.8)	4.4 (3.8 to 5.1)	3.5 (2.9 to 4.1)	<0.001
Perinatal causes	–	2.0 (1.2 to 2.8)	7.0 (6.2 to 7.8)	5.1 (4.4 to 5.7)	0.015
Other causes	–	9.3 (7.8 to 11.0)	9.4 (8.6 to 10.4)	10.2 (9.4 to 11.3)	0.196
Any cause[a]	23.7 (21.6 to 25.9)	18.1 (16.1 to 20.1)	19.2 (17.9 to 20.4)	16.8 (15.7 to 18.0)	<0.001
Mean number of hospitalizations/child	0.4 (0.8)	0.3 (0.8)	0.3 (0.6)	0.2 (0.7)	<0.001

[a]The total number of children admitted to hospital does not correspond to the sum of the groups of causes, because some children may have been admitted more than once due to different causes.

**P*-value for chi square test for linear trend in the four cohorts.

Table 2. Percentages of cohort children admitted to NICU according to sex, family income and maternal skin colour

Variable	Birth cohort year				*P*-value**
	1982 % (95% CI)	1993 % (95% CI)	2004 % (95% CI)	2015 % (95% CI)	
Sex		*P* = 0.927*	*P* = 0.116*	*P* = 0.041*	
Male	–	2.6 (1.5; 3.7)	5.7 (4.7; 6.7)	7.5 (6.4; 8.6)	<0.001
Female	–	2.7 (1.7; 3.7)	4.6 (3.6; 5.5)	5.9 (4.8; 6.9)	<0.001
Difference male–female	–	−0.1	1.1	1.6	
Ratio male/female	–	1.0	1.2	1.3	
Family income (quintiles)		*P* = 0.221*	*P* = 0.216*	*P* = 0.532*	
Q1 (poorest)	–	2.5 (1.0; 4.0)	6.5 (4.8; 8.3)	7.6 (5.7; 9.5)	0.002
Q2	–	3.7 (1.8; 5.6)	5.0 (3.5; 6.6)	6.7 (5.0; 8.5)	0.025
Q3	–	2.1 (0.5; 3.7)	3.9 (2.5; 5.3)	5.9 (4.3; 7.6)	0.003
Q4	–	2.3 (0.7; 3.9)	5.5 (4.0; 7.1)	6.3 (4.7; 8.0)	0.013
Q5 (richest)	–	1.8 (0.5; 3.1)	4.7 (3.2; 6.2)	6.9 (5.1; 8.7)	<0.001
Slope index of inequality	–	−0.7 (−5.0; 3.5)	−1.6 (−4.1; 0.9)	−0.9 (−3.6; 1.9)	
Concentration index	–	−1.7 (−14.8; 11.4)	−4.2 (−12.2; 3.8)	−1.9 (−8.8; 5.0)	
Maternal skin colour		*P* = 0.003*	*P* = 0.752*	*P* = 0.196*	
White	–	2.1 (1.4; 2.8)	5.1 (4.3; 5.9)	7.0 (6.1; 7.9)	<0.001
Brown	–	3.8 (0.0; 8.5)	4.8 (2.2; 7.3)	6.3 (4.2; 8.4)	0.280
Black	–	5.1 (2.5; 7.8)	5.4 (3.8; 7.0)	5.6 (3.8; 7.5)	0.768
Difference Black-White	–	3.0	0.3	−1.4	
Ratio Black/White	–	2.4	1.1	0.8	

**P*-values for differences within each cohort.

***P*-values for time trends within each category.

The frequency of hospitalization for all causes is presented in Table 3. Important socioeconomic differences were observed in all four cohorts. There was no evidence of an interaction between sex and cohort year ($p = 0.214$), so that the results from the four cohorts were pooled. Overall, boys were 23% [95% confidence intervalCI) 1.13 to 1.33] more likely than girls to be admitted in all four cohort. In 1982, 35% of the poorest babies were hospitalized compared with 8.2% in the richest quintile. Over the three decades, admissions in the poorest quintile fell from 35.7% to 23.9%, whereas no changes over time were observed in the two richest quintiles. There was evidence of an interaction between income and cohort year ($p = 0.020$). The SII was reduced from -33.0% points in 1982 to −15.9 in 2015, and the CIX from −23.9 to −15.4. For maternal skin colour, there was no evidence of interaction ($p = 0.299$) and the pooled prevalence ratio was 1.26 (95% CI 1.16 to 1.38).

In Table 4, results for hospital admissions due to diarrhoea are presented. Within any cohort, there were no differences by sex of the child. From 1982 to 2015, admissions were reduced from 6.7% to 0.4% in males and

Table 3. Percentages of cohort children admitted to a hospital due to any cause during the first year of life, according to sex, family income and maternal skin colour

Variable	Birth cohort year				*P*-value**
	1982 % (95% CI)	1993 % (95% CI)	2004 % (95% CI)	2015 % (95% CI)	
Sex	*P* = 0.031*	*P* = 0.142*	*P* = 0.208*	*P*<0.001*	
Male	26.2 (23.0 to 29.4)	19.6 (16.7 to 22.5)	19.9 (18.2 to 21.7)	19.7 (18.0 to 21.4)	0.005
Female	21.4 (18.4 to 24.3)	16.7 (14.0 to 19.4)	18.3 (16.6 to 20.1)	13.8 (12.3 to 15.4)	<0.001
Difference male -female	4.8	3.2	1.6	5.9	
Ratio male/female	1.2	1.2	1.1	1.4	
Family income (quintiles)	*P*<0.001*	*P*<0.001*	*P*<0.001*	*P*<0.001*	
Q1 (poorest)	35.7 (29.4 to 42.0)	24.2 (18.7 to 29.7)	24.8 (21.7 to 27.8)	23.9 (20.9 to 26.8)	0.004
Q2	30.9 (25.8 to 36.1)	20.0 (15.3 to 24.6)	23.4 (20.4 to 26.4)	20.1 (17.3 to 22.8)	0.002
Q3	29.3 (24.3 to 34.4)	15.4 (10.8 to 20.0)	19.6 (16.8 to 22.4)	15.7 (13.2 to 18.3)	<0.001
Q4	17.5 (13.2 to 21.7)	15.9 (11.1 to 20.6)	15.4 (12.9 to 17.9)	13.8 (11.4 to 16.2)	0.113
Q5 (richest)	8.2 (5.1 to 11.3)	8.0 (4.6 to 11.3)	12.7 (10.4 to 15.1)	10.8 (8.6 to 12.9)	0.107
Slope index of inequality	−33.0 (−39.8 to −26.1)	−13.8 (−21.2 to −6.3)	−15.7 (−19.9 to −11.5)	−15.9 (−19.9 to −11.9)	
Concentration index	−23.9 (−28.6 to −19.2)	−10.0 (−15.9 to −4.1)	−13.6 (−17.3 to −9.9)	−15.4 (−19.3 to −11.5)	
Maternal skin colour	*P* = 0.024*	*P* = 0.297*	*P* = 0.045*	*P*<0.001*	
White	22.5 (20.2 to 24.9)	16.7 (14.3 to 19.1)	18.3 (16.9 to 19.8)	15.1 (13.8 to 16.4)	<0.001
Brown	29.0 (23.4 to 34.5)	19.2 (9.5 to 29.0)	21.8 (16.8 to 26.7)	20.3 (16.8 to 23.7)	0.075
Black		19.5 (14.2 to 24.8)	21.2 (18.3 to 24.1)	22.0 (18.7 to 25.3)	
Difference Black-White	6.5	2.8	2.9	6.9	
Ratio Black/White	1.3	1.2	1.2	1.5	

**P*-values for differences within each cohort.
***P*-values for time trends within each category.

from 5.9% to 0.3% in females. Except for 2015 when diarrhoea admissions were extremely rare, the frequencies were much higher among children in the poorest quintile than in the richest quintile. Absolute inequalities fell from -11.7% points in 1982 to -0.1 in 2015, with confidence intervals that did not overlap. Relative inequalities remained stable from 1982 to 2004, with a marked drop in 2015. Possibly because of very small numbers in 2015, the Poisson regression test for interaction between income and cohort year had a large *p*-value of 0.820; this test refers to relative inequalities, given the multiplicative nature of Poisson regression. Regarding skin colour, there was no interaction with cohort year ($p = 0.562$) and the pooled analysis of the four cohorts showed a 40% excess (95% CI 1.00 to 1.95) of diarrhoea admissions for children born to Black or Brown mothers, compared with those with White mothers.

Analysis for hospital admissions due to perinatal causes (Supplementary Table S1, available as Supplementary data at *IJE* online) and pneumonia (Supplementary Table S2, available as Supplementary data at *IJE* online) are presented in the Supplementary materials, available as Supplementary data at *IJE* online. In general, the patterns of associations and trends are similar to those observed for diarrhoea.

All analyses were repeated including only the first admission for each child, and results were virtually unchanged (data not presented).

Discussion

Our results show an increase in NICU use after birth from 1993 to 2015. This was likely related to the sharp increase in preterm deliveries during the period, from about 6% in 1982 to 15% in 2015,[15] as well as to the increased availability of NICU beds in more recent years. In 2004 and 2015, neither socioeconomic nor ethnic inequalities in NICU admissions were evident, but boys were more likely to be admitted than girls. The largest increases over time were observed for babies born to White mothers (from 2.1 in 1993 to 7.0 in 2015) and to women in the highest income group (from 1.8 to 6.9). Possible reasons for these trends are discussed below.

The prevalence of hospitalizations in the first year of life decreased by about one-third. The decline was limited to the poorer quintiles, as admission rates were stable over time in the two richest quintiles. Despite the observed decrease in the gaps between socioeconomic groups, important inequalities still persist. Among causes for which data are available, the fastest decline was for diarrhoea,

Table 4. Percentages of cohort children admitted to a hospital due to diarrhoea during the first year of life, according to sex, family income and maternal skin colour

Variable	Birth cohort year				*P*-value**
	1982 % (95% CI)	1993 % (95% CI)	2004 % (95% CI)	2015 % (95% CI)	
Sex	*P* = 0.544*	*P* = 0.944*	*P* = 0.564*	*P* = 0.637*	
Male	6.7 (4.9 to 8.5)	2.4 (1.1 to 3.6)	1.1 (0.6 to 1.5)	0.4 (0.1 to 0.7)	<0.001
Female	5.9 (4.2 to 7.6)	2.4 (1.2 to 3.6)	0.9 (0.5 to 1.3)	0.3 (0.0 to 0.5)	<0.001
Difference male -female	0.8	0.0	0.1	0.1	
Ratio male/female	1.1	1.0	1.1	1.3	
Family income (quintiles)	*P*<0.001*	*P* = 0.001*	*P*<0.001*	*P* = 0.615*	
Q1 (poorest)	12.1 (7.8 to 16.3)	6.0 (2.8 to 9.0)	2.3 (1.3 to 3.4)	0.1 (0.0 to 0.4)	<0.001
Q2	7.2 (4.3 to 10.1)	2.7 (0.8 to 4.5)	1.0 (0.3 to 1.7)	0.7 (0.2 to 1.3)	<0.001
Q3	8.5 (5.4 to 11.6)	1.2 (0.0 to 2.6)	0.9 (0.2 to 1.6)	0.2 (0.0 to 0.6)	<0.001
Q4	3.6 (1.5 to 5.6)	1.4 (0.0 to 2.9)	0.4 (0.0 to 0.8)	0.5 (0.0 to 1.0)	<0.001
Q5 (richest)	1.6 (0.2 to 3.1)	0.6 (0.0 to 1.6)	0.4 (0.0 to 0.8)	0.1 (0.0 to 0.4)	0.005
Slope index of inequality	−11.7 (−16.2 to −7.1)	−5.2 (−8.7 to −1.6)	−2.3 (−3.5 to −1.0)	−0.1 (−0.6 to 0.4)	
Concentration index	−28.5 (−38.5 to −18.5)	−30.9 (−48.7 to −13.1)	−36.5 (−53.2 to −19.8)	−2.7 (−23.1 to 17.7)	
Maternal skin colour	*P* = 0.447*	*P* = 0.026*	*P* = 0.447*	*P* = 0.525*	
White	6.1 (4.7 to 7.4)	1.8 (1.0 to 2.6)	0.9 (0.6 to 1.3)	0.3 (0.1 to 0.6)	<0.001
Brown	7.3 (4.2 to 10.5)	6.1 (0.0 to 12.3)	0.7 (0.0 to 1.8)	0.0	<0.001
Black		4.1 (1.2 to 6.9)	1.3 (0.5 to 2.1)	0.7 (0.0 to 1.3)	
Difference Black-White	1.2	2.3	0.4	0.4	
Ratio Black/White	1.2	2.3	1.4	2.3	

**P*-values for differences within each cohort.
***P*-values for time trends within each category.

followed by pneumonia, whereas the relative share of perinatal causes increased markedly. Our results on hospital admissions are fully consistent—in terms of time trends, causes and socioeconomic disparities—with our analyses on infant mortality in the four cohorts, which are presented in an accompanying article in this issue.[16] These analyses showed that infant mortality rates fell from 36.4 in 1982 to 13.8 per 1000 live births in 2015, with particularly rapid reductions in infectious causes.

A detailed study of which factors are likely responsible for the decline in admissions in Pelotas is beyond the scope of this analysis. An in-depth study of factors associated with the improved health and reduced mortality of Brazilian children since 1990[17] shows the importance of changes in social determinants of health due to: poverty reduction (particularly the important increase in the value of the minimum wage and a massive programme of conditional cash transfers for poor families); improved access to health care with the creation of a national health system; vertical health programmes against infectious diseases (including diarrhoea, pneumonia and vaccine-preventable diseases); and improved breastfeeding practices, paralleled by a sharp reduction in undernutrition. Such national-level changes were also occurring in Pelotas. From 1982 to 2015, standards of housing, sanitation and water supply improved markedly, as well as levels of parental education and family income.[10] Although low birthweight remained stable,[15] undernutrition in infancy was markedly reduced.[18] Parental smoking was also reduced.[19] The prevalence of exclusive breastfeeding at 3 months, and of continued breastfeeding at 12 months, increased sharply.[20] All of these changes must have contributed to reduced frequency of hospital admissions.

It is also important to account for changes in access to health care. In 1982, children from poor families were mostly admitted to a charity hospital ran by the Catholic Church. A common reason for admission for infectious diseases was the fact that poor families could not afford outpatient antibiotic treatment, and thus had to be admitted in order to receive such drugs at no out-of-pocket costs. In 1989, a universal national health system was created, which increased access for all citizens to inpatient and outpatient care. Access to antenatal, delivery and child health care also improved markedly after implementation of the national health service.[21] In spite of increased access, however, hospital admission rates as well as mortality continued to decline, which suggests that children became healthier (which is consistent with the sharp reduction in undernutrition),[18] and/or that increased access to outpatient care, including free antibiotics, reduced the need for hospital admission. Outpatient services were greatly expanded with the creation of the Family Health Strategy, a national programme launched in the 1990s[22] which provided free care in low-income neighbourhoods. Both of the leading causes of hospitalization in 1982—diarrhoea and pneumonia—are highly sensitive to primary health care, and therefore the expansion of the Family Health Strategy is likely to have contributed to the decline in these causes.[23]

On the other hand, the marked increase in NICU admissions, in parallel with the growing prevalence of preterm births, has been related to poor quality of health care and to excessive medicalization of childbirth, including the fact that caesarean sections now account for over 60% of all deliveries in the city.[15,21] Other articles in this supplement report on the increases in caesarean sections, in preterm and in early term deliveries, all of which may have contributed to the rise in NICU admissions[24] by leading to iatrogenic premature births.[15,21] It is noteworthy that the most rapid increases in admissions were observed for babies born to White and to high-income mothers—who are most likely to suffer excessive medicalization.

Our findings of a decline in all-cause hospitalizations, and particularly those due to diarrhoea and pneumonia, accompanied by an increase in perinatal causes, are similar to what is observed in Brazilian official data produced by the Unified Health System (SUS).[4] From 1998 to 2015, all-cause admission rates decreased from 244 to 190 per 1000 live births. Similar trends were reported for hospitalizations due to respiratory diseases (from 85 to 52 per 1000 live births) and for other infectious diseases (from 56 to 23 per 1000 live births). The national data also reflect our observation of an increase in admissions due to perinatal conditions (from 59 to 80 per 1000 live births).[4]

Our analyses have the advantage of allowing disaggregation by socioeconomic position and skin colour, which is not possible with the national information system. Our findings on inequalities are consistent with earlier analyses from Pelotas,[11] as well as with a study conducted in northeast Brazil in which children from low-income families were 2.3 times more likely to be admitted than children from better-off families.[25]

Our finding of inverse associations between child hospitalizations and socioeconomic position are also consistent with the literature from high-income countries like the USA,[26,27] Canada[28] and the UK.[2,6,29,30] It appears that when economic barriers to hospitalization are small or non-existent, higher morbidity and severity of illnesses associated with poverty lead to higher admission rates among disadvantaged children compared with children from better-off families.

The literature on child hospitalizations according to socioeconomic position in low-income countries is very scarce, but it is likely that barriers to accessing hospital care may prevent children from poor families being admitted. Two studies from Tanzania report direct associations between socioeconomic position and child hospitalizations.[31,32]

We found that infants born to mothers with brown or black skin colour were about 30% more likely to be admitted during infancy than those born to white-skinned mothers, which is likely associated with family income.[10] Again, these results are consistent with the ethnic group inequalities reported in high-income countries.[2,6,33,34] It is possible that the lack of differences in hospitalizations according to skin colour observed in 2004 and 2015, as opposed to 1993, could be due to the reduced frequency of diarrhoea and pneumonia admissions among non-Whites, as well as to increased hospitalizations of preterm babies among better-off, predominantly White families.[15]

Our study has limitations. The first refers to ascertainment and classification of causes for admissions. In 1982, only diarrhea—the major cause for admission—and other causes were recorded at the 12-month interview. In 2004 and 2015, information collected at 12 months referred to several groups of causes. In 1993, a prospective sub-study collected detailed information on causes of admission based on interviews with the parents and review of hospital casenotes.[35]

It is unlikely, however, that these differences would have distorted the present findings, given the consistent time trends observed for the four cohorts. Information on NICU admissions was collected at the postnatal interview, when newborns were still in intensive care, and is unlikely to have been biased. Other limitations of our analyses—including the collection of information on skin colour and family income, and losses to follow-up—are discussed in the first article in this Supplement.[10]

Our findings regarding cause-specific time trends and inequalities associated with income and skin colour are consistent with the results on infant mortality.[16] The reasons behind the reported improvements are multiple, including a reduction in poverty, increased parental educational levels, lower fertility and better housing, water supply and sanitation, as well as important improvements in breastfeeding practices and a reduction in maternal smoking.[10,16,19,21,36] A more detailed discussion of the likely reasons behind the improvements in child health and nutrition in Brazil is available elsewhere.[17] In spite of overall progress, important challenges remain such as the increase in admissions related to prematurity, and persistent social and ethnic group inequalities. Policies in the health and other sectors must be strengthened in order to address the remaining challenges.

Supplementary data

Supplementary data are available at *IJE* online.

Funding

The four cohorts received funding from the following agencies: Wellcome Trust, International Development Research Center, World Health Organization, Overseas Development Administration of the United Kingdom, European Union, Brazilian National Support Program for Centers of Excellence (PRONEX), Brazilian National Council for Scientific and Tehcnological Development (CNPq), Science and Technology Department (DECIT) of the Brazilian Ministry of Health, Research Support Foundation of the State of Rio Grande do Sul (FAPERGS), Brazilian Pastorate of the Child, and Brazilian Association for Collective Health (ABRASCO).

Pelotas Cohorts Study Group

Aluisio J D Barros,[1] Alicia Matijasevich,[2] Diego G Bassani,[3] Helen Gonçalves,[1] Joseph Murray,[1] Luciana Tovo-Rodrigues,[1] Maria Cecilia F Assunção,[1] Mariangela F Silveira,[1] Marlos Rodrigues Domingues[1] and Pedro R C Hallal.[1]

[1]Federal University of Pelotas, Brazil, [2]University of São Paulo, Brazil and [3]University of Toronto, Canada.

Conflict of interest: None declared.

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