The challenge of reducing neonatal mortality in middle-income countries: findings from three Brazilian birth cohorts in 1982, 1993, and 2004

Fernando C Barros, Cesar G Victora, Aluisio J D Barros, Ina S Santos, Elaine Albernaz, Alicia Matijasevich, Marlos R Domingues, Iândora K T Sclowitz, Pedro C Hallal, Mariângela F Silveira, J Patrick Vaughan

Lancet 2005; 365: 847–54

Published online March 3, 2005 http://image.thelancet.com/extras/04art11026web.pdf

See **Comment**

PAHO/WHO Latin American Centre for Perinatology and Human Development, Montevideo, Uruguay (F C Barros MD); **Universidade Federal de Pelotas, Pelotas, Brazil** (Prof C G Victora MD, A J D Barros MD, I S Santos MD, A Matijasevich MD, M R Domingues MSc, I K T Sclowitz MD, P C Hallal MSc, M F Silveira MD); **Universidade Católica de Pelotas, Pelotas, Brazil** (E Albernaz MD), **London School of Hygiene and Tropical Medicine, London, UK** (Prof J P Vaughan MD)

Correspondence to: Dr Fernando C Barros, PAHO/WHO Latin American Centre for Perinatology and Human Development, Hospital de Clinicas, Piso 16, 11300 Montevideo, Uruguay **barrosfe@clap.ops-oms.org**

Summary

Background **Middle-income countries will need to drastically reduce neonatal deaths to achieve the Millennium Development Goal for child survival. The evolution of antenatal and perinatal care indicators in the Brazilian city of Pelotas from 1982 to 2004 provides a useful case study of potential challenges.**

Methods **We prospectively studied three birth cohorts representing all urban births in 1982, 1993, and from January to July, 2004. The same methods were used in all three studies.**

Findings **Despite improvements in maternal characteristics, prevalence of preterm births increased from 6·3% (294 of 4665) in 1982 to 16·2% (342 of 2112) in 2004, corresponding to a 47 g reduction in mean birthweight. Average number of antenatal visits in 2004 was 8·3 per woman, but quality of care was still inadequate—97% of women had an ultrasound scan, but only 1830 (77%) had a vaginal examination and 559 of 1748 non-immunised women did not receive tetanus toxoid. Rate of caesarean sections increased greatly, from 28% (1632 of 5914) in 1982 to 43% (1039 of 2403) in 2004, reaching 374 of 456 (82%) of all private deliveries in 2004. The increased rate of preterm births seemed to result largely from caesarean sections or inductions. Newborn care improved, and gestational-age-specific mortality rates had fallen by about 50% since 1982. As a result, neonatal mortality rates had been stable since 1990, despite the increase in preterm deliveries.**

Interpretation **Excessive medicalisation—including labour induction, caesarean sections, and inaccurate ultrasound scans—led by an unregulated private sector with spill-over effects to the public sector, might offset the gains resulting from improved maternal health and newborn survival. These challenges will have to be faced by middle-income countries striving to achieve the child survival Millennium Development Goal.**

Introduction

The fourth Millennium Development Goal (MDG) entails the reduction of child mortality by two-thirds by the year 2015, from the base year of 1990. About 40% of the 10·8 million annual deaths of children younger than 5 years (under-5) take place in the neonatal period, and the relative importance of these deaths increases as child mortality is reduced.[1,2] When under-5 mortality is less than 35 per 1000, more than 50% of all children dying are neonates.[1] This situation is present in 62% of the world's countries classified in the middle-income group,[3,4] including Brazil.[5] These countries, where neonatal mortality rates are 20 per 1000 or below, will fail to reach the MDG unless they succeed in preventing neonatal deaths.

Current levels of neonatal mortality in developed countries are often around 3–4 per 1000,[6] and thus there is considerable room for improvement in middle-income countries. However, further reduction of neonatal mortality from baseline levels of less than 20 per 1000 presents special challenges. We did three birth-cohort studies comprising all births taking place in 1982, 1993, and 2004 in the city of Pelotas in southern Brazil. These three investigations presented an opportunity to assess trends in the health of mothers and newborn babies in an urban area of a middle-income country, with high-quality data. We describe trends in maternal health and nutrition, fetal and neonatal mortality, gestational age, and birthweight, and their possible determinants. We also discuss how these outcomes might have been affected by changes in health-care practices, with emphasis on the role of the private sector.

Methods

Brazil is a middle-income country with a population of 182 million inhabitants and a gross domestic product per head of US$7700. More than 90% of the country's 3·1 million annual births take place in hospitals, and 93% of pregnant women receive antenatal care. In 2002, mortality rates in under-5s, infants, and neonates were 33, 27, and 17 per 1000 livebirths, respectively, with 65% of all infant deaths in the neonatal period and 50% in the first week of life.[7] The country has one of the highest rates of caesarean sections in the world—38% in 2001.[8]

Pelotas is a city of 320 000 inhabitants, located in the far south of Brazil. The 1982 birth cohort study included all births in the city's four maternity hospitals during that year.[9,10] Subsequent studies showed that more than 98% of births in the city took place in these hospitals. Mothers who were resident in the Pelotas urban area were interviewed soon after giving birth about biological, demographic, reproductive, behavioural, and socioeconomic characteristics, and information on the current and previous pregnancies. Mothers and babies were weighed with calibrated scales. Fetal and neonatal mortality were monitored through regular visits to hospitals, cemeteries, vital registration offices, and the city's health department. Exactly the same procedures were used in the 1993[9,10] and 2004 birth cohort studies. Data from the 2004 study refer to the period from Jan 1 to July 31, because data were still being collected when this article was submitted. In the 1982 and 1993 studies, no important seasonality was noted in any of the indicators described here.

Most deliveries occur in three private, non-profit hospitals that cater for patients who fall into three major categories: government-funded universal health insurance (created in the late 1980s), private health insurance, or fully private (paying directly to the doctor and hospital). In 1982, before government health insurance became universal, there was a fourth category of "indigent" patients who received care in a Catholic hospital. This category has been merged with the national insurance group in the present analyses. A shift from fully private care to the private insurance group has also occurred, and we merged these two groups in the analyses. Women in this category are entitled to private or semi-private rooms, and have their babies delivered by the same doctor who did antenatal care.

In the three cohort studies, birthweights were measured and recorded by hospital staff with paediatric scales that were regularly calibrated by the research team. Gestational age was calculated from the date of the last menstrual period provided by the mother or obtained from her antenatal care card. Small for gestational age infants included those with a birthweight for gestational age below the tenth percentile of a Canadian reference.[11] When birthweight was 4 SD or more above or below the mean reference birthweight for gestational age, the infants were excluded from the gestational age analyses.[12] In both the 1993 and 2004 cohorts, all newborns were examined by a trained field worker to assess gestational age.[13]

In 1982, the prevailing definition of a stillbirth was used (death in a fetus with a gestational age of 28 weeks or greater, or weight of 1000 g or more if no information on duration of pregnancy was available). The same definition was used in 1993 and 2004 in the present comparisons. Data from officially registered deaths were also used to describe changes in mortality for the years between the studies.

Data files for the three cohorts were merged. Differences and trends across the three cohorts were tested with χ^2 tests for categorical outcomes and one-way analysis of variance for numerical variables. Whenever applicable, tests for linear trends were used, through linear regression for numerical outcomes and logistic regression for categorical outcomes. Logistic regression was also used to test differences in rates of caesarean sections and preterm births between cohorts, type of payment, and the interaction between these two explanatory variables. The expected neonatal mortality rates in 2004 with the 1982 distributions of birthweight and gestational age were obtained through direct standardisation, applying the specific 2004 rates (<1500 g, 1500–2499 g, and ≥2500 g for birthweight and ≤34, 35–36, and ≥37 weeks for gestational age) to the 1982 distribution of livebirths. A linear regression model was used to estimate differences in mean birthweight between the three cohorts, adjusting for changes in maternal characteristics (height, weight, schooling, marital status, ethnic origin, smoking, age, parity, and birth intervals).

The three cohort studies were approved by the Medical Ethics Committee of the Federal University of Pelotas, affiliated with the Brazilian Federal Medical Council. Oral informed consent was given by mothers in 1982 and 1993. In 2004, written informed consent was obtained from mothers.

Role of the funding sources
The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results
Table 1 shows the characteristics of mothers and their pregnancies in the three birth cohorts. The total number of births decreased from 6011 in 1982 to 5304 in 1993; in the first 7 months of 2004 there were 2427 births, equivalent to about 4200 births in a year. The corresponding numbers of stillbirths were 97, 55, and 24, and these births were excluded from all analyses except that of fetal mortality. Rates of refusal to be interviewed were lower than 1% in the three cohorts. Multiple births accounted for 49 (0·8%) deliveries in 1982, 39 (0·7%) in 1993, and 28 (1·2%) in 2004 (p=0·2). These births were included in all analyses.

Over the 22 years covered by the study, important changes in maternal characteristics were noted (table 1). Mothers in 2004 were, on average, 4·5 cm taller (SE –0·17) and 5·1 kg heavier (–0·26) than those who gave birth in 1982. Level of education increased and the proportion of mothers smoking fell. Mean maternal age hardly changed, but the proportions of mothers aged younger than 20 years and older than 34 years increased. The proportion of single mothers almost doubled. The proportion of mothers classified by the interviewers as of black or mixed ethnic origin increased. Parity hardly changed, but birth intervals were substantially longer in 2004. Antenatal care indicators improved substantially, in particular the proportion of mothers whose initial visit was in the first trimester, and the mean number of antenatal visits increased.

Information on ultrasound examinations was available for 2004 only; 84 of 2373 (3·5%) mothers did not have a scan, 878 (36·7%) had one scan, 677 (28·5%) had two, and 734 (31·3%) had three or more. The mean fetal age at the first ultrasound scan was 20·0 weeks (SD 7·6), ranging from 14·2 (7·1) weeks in the private to 21·0 (SD 7·2) weeks in the public sector. Other antenatal procedures were less frequent: 543 of 2373 (23%) women had no vaginal examinations during antenatal care, and 1189 of 1748 (68%) who were not previously immunised against tetanus reported receiving one or more doses of this vaccine.

Table 2 shows information about the deliveries and newborns. The proportion of women receiving private care increased between 1982 and 2004, as did the proportion of caesarean deliveries. Figure 1 shows that most of the increase was due to the private sector, where no fewer than 82·3% of deliveries in 2004 were by caesarean section (figure 1). The interaction between year and type of delivery was highly significant (p<0·0001).

Other results showed an increase in medical interventions during this period (table 2). The proportion of deliveries assisted by medical doctors rose between 1982 and 1993, and then remained stable at 88% between 1993 and 2004. Information on induced deliveries was obtained from the mothers, and might not be fully accurate. Nevertheless, a major increase was reported, from 2·5% (147 of 5914) in 1982 to 43·0% (1026 of 2386) in 2004. Inductions were common in all gestational age groups: in 2004, 38·7% (128 of 339) for less than 37 weeks, 38·5% (220 of 571) for 37–38 weeks, and 46·5% (558 of 1192) for 39 weeks or more. The presence of a paediatrician in the delivery room was not ascertained in 1982, but increased between 1993 and 2004.

Regarding birth outcomes, there was a 47 g (SE –13·6) decrease in the mean birthweight in the period, and the proportion of children lighter than 2500 g rose (table 2), primarily due to an increase in the proportion of preterm births. The proportion of infants with a gestational age of 39 weeks or more declined. The prevalence of preterm deliveries according to physical examination (Dubowitz score) also increased, from 437 of 5139 babies (8·5%) in 1993 to 316 of 2340 (13·5%) in 2004. This examination was not done in 1982. However, the prevalence of small for gestational age babies did not show any clear trends (table 2).

In 1982, rates of preterm births were 6·5% (49 of 759) for private and 6·3% (245 of 3906) for public sector newborns; by 1993, these rates were 7·4% (49 of 664) and 11·3% (449 of 3964), and in 2004, 12·1% (51 of 420) and 17·2% (291 of 1692), respectively. The increase in the public sector seemed to be greater than in the private sector, although the interaction was not significant (p=0·06).

	Birth cohort (year)			p
	1982	1993	2004 (Jan–Jul)	
Number of livebirths	5914	5249	2403	
Height (cm)				
Mean (SD)	156·4 (6·0)	159·8 (6·8)	160·9 (6·9)	0·0001*
<150	637 (11·0%)	239 (4·6%)	69 (3·9%)	0·0001*
Pre-gestational weight (kg)				
Mean (SD)	55·7 (9·6)	58·2 (10·5)	60·8 (12·1)	0·0001*
<49	1168 (23·1%)	805 (15·7%)	256 (11·4%)	0·0001*
Schooling (years)				
Mean (SD)	6·5 (4·2)	6·7 (3·6)	8·0 (3·5)	0·0001*
0	327 (5·5%)	130 (2·5%)	29 (1·2%)	0·0001*
≥9	1493 (25·3%)	1350 (25·8%)	1021 (42·8%)	0·0001*
Ethnic origin				0·0001*
White	4851 (82·1%)	4058 (77·3%)	1754 (73·1%)	
Mixed/black	1060 (17·9%)	1189 (22·7%)	646 (26·9%)	
Age (years)				
Mean (SD)	25·8 (6·1)	26·0 (6·4)	26·2 (6·8)	0·006*
<20	912 (15·4%)	915 (17·4%)	440 (18·3%)	0·0001*
≥35	586 (9·9%)	577 (11·0%)	337 (14·0%)	0·0001*
Smoking during pregnancy	2103 (35·6%)	1752 (33·4%)	665 (27·7%)	0·0001*
Single mother	485 (8·2%)	649 (12·4%)	394 (16·4%)	0·0001*
Parity				
0	2322 (39·3%)	1843 (35·1%)	907 (37·8%)	0·0001*
≥3	964 (16·3%)	1000 (19·1%)	465 (19·4%)	0·0001*
Birth interval (months)				
Mean (SD)	44·9 (34·1)	58·5 (41·3)	66·7 (46·9)	0·0001*
<24	1123 (30·6%)	587 (19·2%)	193 (16·0%)	0·0001*
Antenatal care				
≥1 attendances	5589 (94·9%)	4987 (95·2%)	2276 (98·6%)	0·0001*
Antenatal care started in first trimester	1124 (61·5%)	3579 (72·3%)	1739 (74·2%)	0·0001*
Mean (SD) number of antenatal visits	6·6 (3·2)	7·7 (3·7)	8·3 (3·3)	0·0001*

Data are number (% of total number of livebirths in year) unless otherwise stated. *Test for linear trend.

Table 1: **Maternal characteristics**

The increase in preterm births and the reduction in mean birthweight between 1982 and 2004 (table 3) affected both vaginal and caesarean section deliveries. Inaccurate ultrasound results might increase rates of preterm deliveries by leading doctors to induce labour or do caesarean sections too early. We used data from the cohort to assess the difference between gestational ages assessed through ultrasound examination and according to the date of the last menstrual period. For babies who, according to the latter measure, had a gestational age of 32–36 weeks, ultrasound scans overestimated gestational age by 1·5 weeks (SD 2·6); for public sector patients the difference was 1·8 weeks (2·3), and in the private sector 0·7 weeks (3·2). These analyses were restricted to scans done in the first 20 weeks of pregnancy.

Mortality rates are also shown in table 2; late fetal mortality rate fell substantially between 1982 and 2004. Figure 2 shows neonatal, post-neonatal, and infant mortality rates by year, using information from the

	Birth cohort (year)			p
	1982	1993	2004 (Jan–Jul)	
Number of livebirths	5914	5249	2403	
Type of payment				0·0001*
Private care or private insurance	867 (14·7%)	708 (13·5%)	454 (18·9%)	
Government insurance	5047 (85·3%)	4541 (86·5%)	1946 (81·1%)	
Caesarean sections	1632 (27·6%)	1602 (30·5%)	1039 (43·2%)	0·0001*
Person in charge of delivery				0·0001
Medical doctor	3601 (61·0%)	4630 (88·3%)	2073 (88·5%)	
Auxiliary nurse	1293 (21·8%)	195 (3·7%)	14 (0·6%)	
Medical student or other	1230 (17·2%)	417 (8·0%)	258 (10·9%)	
Paediatrician in delivery room	n/a	2232 (46·9%)	1517 (64·3%)	0·0001
Gestational age (weeks)†				0·0001
<34	49 (1·1%)	111 (2·4%)	83 (3·9%)	
34–36	245 (5·3%)	387 (8·4%)	259 (12·3%)	
37–38	1038 (22·3%)	933 (20·1%)	574 (26·3%)	
≥39	3333 (71·4%)	3197 (69·1%)	1196 (57·5%)	
Missing or implausible data	1249 (21·1%)	621 (11·8%)	291 (12·1%)	0·0001
Pre-term births (<37 weeks)	294 (6·3%)	498 (10·8%)	342 (16·2%)	0·0001*
Birthweight (g)				
Mean (SD)	3187 (565)	3157 (549)	3140 (554)	0·0001*
<1500	64 (1·1%)	46 (0·9%)	34 (1·4%)	0·10
<2500	534 (9·0%)	510 (9·8%)	248 (10·4%)	0·05*
>3500	1620 (27·4%)	1283 (24·5%)	572 (23·9%)	0·0001*
Small for gestational age	1014 (21·7%)	1117 (24·2%)	394 (18·7%)	0·001
Unknown	5	17	6	
Deaths (mortality rates per 1000 births)				
Late fetal (total births)	97 (16·1)	55 (10·4)	24 (9·9)	0·005*
Neonatal (livebirths)	118 (20·0)	75 (14·3)	28 (11·7)	0·003*
Postneonatal (livebirths)	92 (15·6)	36 (6·8)	n/a	0·0001

Data are number (% of total number of livebirths in year) unless otherwise stated. n/a=information not available. *Test for linear trend. †Excludes mothers who did not recall the date of their last menstrual period or who provided a date that was not compatible with the birthweight.

Table 2: **Delivery and newborn characteristics**

cohort studies and the vital registration, which from 1993 onwards was deemed to be nearly complete. There were important declines in the 1980s, but mortality rates were virtually unchanged in the 1990s. The neonatal mortality rate in 2004 is based on only 28 deaths. When using official data, the possibility of under-registration has to be considered. In 1982, 24% of all infant deaths were not registered, but the 1993 study showed that registration improved and only 5% of deaths were not registered.[14] In 2004, all deaths so far were registered.

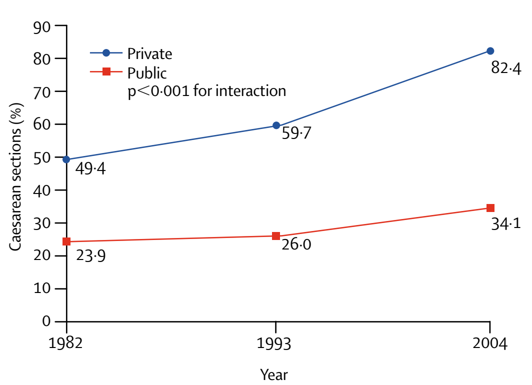

Figure 1: **Caesarean section rates in the public and private sectors**

Gestational-age-specific and birthweight-specific neonatal mortality seemed to fall steadily in practically all groups from 1982 to 2004 (table 4). Again, results for 2004 should be interpreted with caution because numbers were small, especially in the categories with few deaths. Applying the 2004 birthweight-specific mortality rates to the 1982 birthweight distribution, neonatal mortality in 2004 would fall to 9·1 per 1000, a reduction of 22% compared with the current value. When standardised for gestational age, the reduction was even greater: we would expect a neonatal mortality rate of 6·0 per 1000, a 49% reduction.

We noted important changes during these two decades in several maternal characteristics associated with birthweight, including height, weight, schooling, marital status, ethnic origin, smoking, age, parity, and birth intervals. These variables, using the same categories shown in tables 1 and 2, were entered as confounding factors in a multiple linear regression equation in which the outcome was birthweight. Dummy variables were created to represent the three birth cohorts. Whereas the crude reductions in mean birthweight (table 2) were of 30 g (SE –10·6) between 1982 and 1993, and 47 g (–13·6) between 1982 and 2004, these values increased notably to 95 g (–10·7) and 159 g (–15·2), respectively, after accounting for changes in maternal confounding factors. The latter difference corresponded to a reduction of about 0·29 *Z* score.

Discussion

Data from three population-based birth cohorts spread over 22 years allowed us to investigate some of the challenges associated with improving neonatal health in a middle-income country facing epidemiological and demographic transitions. During this period, we noted substantial improvements in measures associated with maternal health, including decreased fertility (the crude birth rate fell from 27·6 to 12·5 per 1000 inhabitants), increased birth intervals, and higher levels of schooling. Mothers became taller and heavier, and prevalence of smoking during pregnancy decreased. All these factors could be expected to improve neonatal health.[15] On the other hand, we recorded increases—although not as marked—in proportions of teenage mothers, unmarried mothers, and women with high parity.

Major changes in health systems happened in these two decades, of which the most important was the creation of the *Sistema Único de Saúde* (Unified Health System) by the 1988 constitution, ensuring free health care for every citizen. The expansion in health care in Pelotas led to more than 98% of pregnant women receiving some antenatal care, with a mean of 8·3 attendances per mother in 2004. Care during delivery and care of newborn babies also improved.

Mothers with low incomes, who previously gave birth in philanthropic hospitals, became entitled to government insurance. The proportions of births attended by obstetricians and paediatricians increased significantly. There were no neonatal intensive care units in 1982; such units were created in two of the three largest hospitals by 1993, and were substantially expanded in the late 1990s, resulting in more appropriate physical area, a larger number of cots, better-trained staff, universal access to surfactants, and better respirators and laboratory techniques. Infants born in hospitals without neonatal intensive care units are transferred to units in other hospitals when necessary—all hospitals are within a 2 km radius.

Nevertheless, neonatal mortality rates had shown no clear reduction since 1990. These rates could be reduced either by improving the gestational age/birthweight (GA/BW) distribution or by decreasing the GA/BW-specific mortality rates through improved obstetric and newborn care.[16] The relatively stable rates in Pelotas are due to a combination of negative changes in the GA/BW distribution with improvements in GA/BW-specific survival.

Let us consider changes in birthweight. In view of the substantial improvements in maternal health, it is paradoxical that mean birthweight decreased by 47 g between 1982 and 2004, a difference that would be three times greater—159 g—had maternal characteristics in 2004 been those observed in 1982. The prevalence of intrauterine growth restriction, however, was stable, indicating that lower weights were mostly due to shorter gestations. This deduction was confirmed by the finding of a marked increase in preterm births during this period. Previous Brazilian studies had already reported increases in preterm births and in low birthweight.[17–19]

In spite of a worsening in the GA/BW distribution, neonatal mortality did not increase because survival improved in all GA/BW categories (table 4). Applying the 2004 gestational age-specific rates to the 1982 distribution, neonatal mortality in Pelotas would be 6·0 per 1000, or about half of the actual rate of 11·7, which is comparable to that observed in the USA before 1980, more than 25 years ago.[16] These improvements in neonatal survival attest to the effectiveness of changes in neonatal health care.

Therefore, the main reason for lack of progress seems to be the increase in preterm deliveries. There are two possible explanations: either maternal risk factors for premature delivery are increasing, or there were changes in use of medical interventions to interrupt (or not to prolong) pregnancy.

Risk factors for preterm delivery[20] include factors that, according to our data, did not increase markedly in Pelotas: multiple births, low pre-pregnancy body-mass index, previous preterm birth, heavy work during pregnancy, and smoking. Other risk factors might have increased—namely genital tract infection (resulting in premature rupture of membranes [PROM]), pregnancy-induced hypertension, incompetent cervix or abruptio placentae—but our data, which were obtained from the mother, do not allow a detailed investigation. Further research is now under way to address these issues.

To better understand changes in causes of preterm delivery, it is necessary to address the quality of antenatal and delivery care. The increased medicalisation of pregnancy and childbirth led to changes that are at best wasteful, if not downright iatrogenic. We found that 97% of all women had at least one ultrasound scan, and that 31% had three or more scans during pregnancy; these exams are carried out by private providers who are then reimbursed by the government. The value of routine late pregnancy ultrasound screening in unselected populations is controversial.[21] On the other hand, there are indications that the quality of antenatal care is inadequate. Silveira and colleagues[22] examined case-records of a random sample of 839 pregnant women attending antenatal care in the public sector in Pelotas during

	Preterm births		Low birthweight		Mean (SD) birthweight (g)	
	Vaginal	Caesarean	Vaginal	Caesarean	Vaginal	Caesarean
1982	206/3292 (6·3%)	88/1373 (6·4%)	390/4281 (9·1%)	144/1628 (8·9%)	3173 (554)	3226 (591)
1993	328/3189 (10·3%)	170/1439 (11·8%)	354/3635 (9·7%)	156/1597 (9·8%)	3135 (528)	3207 (592)
2004	188/1183 (15·9%)	154/929 (16·6%)	124/1362 (9·1%)	124/1035 (12·0%)	3123 (519)	3161 (597)
p	0·0001*	0·0001*	0·60	0·01*	0·001*	0·002*

*Test for linear trend among cohorts.

Table 3: **Proportion of preterm births and babies of low birthweight by type of delivery and year**

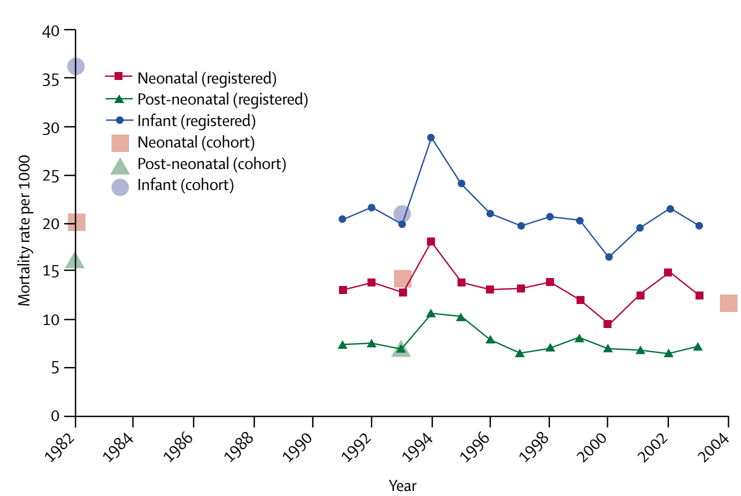

Figure 2: **Time trends in infant mortality rate and its components**

	Birth cohort (year)			p*
	1982	1993	2004 (Jan–Jul)	
Birthweight (g)				0·0001
<1500	44 (688)	28 (609)	13 (382)	
1500–2499	37 (79)	20 (43)	5 (23)	
⩾2500	34 (6)	17 (4)	6 (3)	
Unknown	3 (600)	10 (588)	4 (667)	
Gestational age (weeks)				0·0001
<34	24 (490)	17 (153)	12 (145)	
34–36	8 (33)	5 (13)	5 (19)	
⩾37	35 (8)	19 (5)	6 (3)	
Unknown	51 (41)	34 (55)	5 (17)	
Total	118 (20)	75 (14)	28 (12)	

Data are number of deaths (rate per 1000 in category). *χ^2 test for heterogeneity.

Table 4: **Neonatal mortality rates by birthweight and gestational age**

1998. They showed that ultrasound scans were done in 87% of the women, but only 68% had a blood test for syphilis and 75% received two or more doses of tetanus toxoid. In our 2004 data, no fewer than 23% of mothers reported that they did not have a single pelvic examination despite several antenatal attendances and guidelines from the Ministry of Health.[23] Antenatal care in the public sector is done in government clinics, but laboratory examinations take place in the private sector, which is reimbursed by the government. Local obstetricians report that while an ultrasound scan can usually be obtained within 2 weeks, blood tests normally require 4–6 weeks. Drugs for treating infections during pregnancy are only available from private pharmacies at a cost that many families cannot afford. In the past 4 years, there were 29 cases of congenital syphilis in Pelotas (Pelotas Department of Health, unpublished data), and most of the mothers had attended antenatal care—a paradoxical finding for a highly medicalised setting.

The results on caesarean sections are also a cause for concern. When, 14 years ago, we used data from the 1982 cohort to describe "an epidemic of C-sections" in this journal,[24] we challenged readers by forecasting a rate of almost 70% in 2000; we were wrong in respect of the overall population, but actually quite conservative for private patients, for which the current rate in Pelotas is at the striking level of 82%. Several explanations have been proposed for these extremely high rates, but these are beyond the scope of the present analyses.[25,26]

In developed countries, the use of technologies for preventing stillbirths and neonatal deaths,[27] has been held partly responsible for the observed increases in preterm births.[28–30] In a Brazilian study covering the period from 1978–79 to 1994, the high rate of caesarean sections[18] and the increase in single mothers[31] were suggested as partly responsible for the observed increase in preterm births and decrease in birthweight. Our data (table 3) show similar increases in preterm births for vaginal and caesarean deliveries, suggesting either a common explanation or—less likely—two separate causes acting with similar magnitude.

A possible common explanation is that pregnancy interruptions—through either induction or caesarean section—have become much more frequent. The wide use of ultrasound scans might have contributed to the increase in preterm deliveries, as described elsewhere.[32] Local practice recommends that if gestational age is judged to be 34 weeks or greater, there should be no measures to delay the delivery of a mother arriving with PROM or pre-eclampsia, which were leading causes of preterm delivery in our setting. We suggest that the increased preterm rate might result from either acceleration of delivery—through induction or caesarean section—of fetuses whose gestational age has been overestimated by inaccurate ultrasound results, or at least failure to attempt to delay delivery. Additionally, the poor quality of antenatal care may contribute by failing to control infections that lead to PROM, but our data are not conclusive. Both PROM and inaccurate ultrasound results are more likely to affect public than private sector patients.

The decrease of gestational age with modern perinatal care might indicate interruptions of pregnancies that are justified by risk to the fetus or mother. However, fetal mortality has been stable at around 10 per 1000 in the past decade, and we recorded no evidence of a fall in maternal mortality (data not shown)—although owing to the small number of deaths, such a decline would be difficult to detect.

The data presented here are not necessarily representative of Brazil as a whole. The infant mortality rate in Pelotas was about 20 per 1000, compared with 27 in Brazil; 41% of deliveries were through caesarean section, compared with 38% in the whole country; and the mean number of antenatal visits in the public sector in Pelotas was 7·4, compared with 5·1 for the whole country. As noted, increasing trends in preterm deliveries and low birthweight have been reported in other Brazilian cities. The present findings could have important implications for other middle-income countries facing demographic transition, and where public and private sectors coexist.

First, the adoption of universal health insurance has undoubtedly improved access, but quality of antenatal care seems to be inadequate—the prevalence of babies that are small for their gestational age has hardly changed despite large increases in the number of attendances, and fully preventable diseases such as congenital syphilis still occur.

Second, rapid uptake of medical technology may be wasteful, if not downright harmful. Expectations of pregnant women from all social groups are probably affected by the type of care available to the wealthiest people.[25,33] When pregnancy care for the latter is inappropriately medicalised, as exemplified by the high rates of caesarean section and overuse of ultrasound scans, those expectations could lead to further unnecessary, wasteful, or possibly harmful interventions.

Third, repeated calls have been made for greater involvement of the private sector in delivering care for mothers and children.[34,35] The private sector, however, represents a mixture of for-profit and not-for-profit organisations, with differing expectations and reward systems. Our results lead to the question of whether or not, in settings such as Brazil, it will be possible to restrain the private for-profit section from unduly distorting overall health-care patterns. Also, the peculiar mix of public and private sectors in Brazil, where, for example, ultrasound scans for public sector mothers are done by private sector doctors, might explain the excessive number of examinations and their poor quality.

Furthermore, the importance of collecting population-based, observational data to monitor and assess changes in health interventions and outcomes should be emphasised. In countries where most deliveries take place in hospitals, policymakers should be encouraged to set up perinatal information systems in sentinel maternity wards to produce the type of information reported in this paper, to improve the evidence base for delivery and care of newborn babies. The existence of three successive cohorts has enabled us to understand that the relatively small change in neonatal mortality since 1990 was due to a combination of increased rates of low birthweight and preterm deliveries with improved care of neonates. This information presents new challenges for local and national policymakers, because in order to reach the Millennium Development Goal for child survival, strategies will have to be implemented to improve birthweight and reduce preterm deliveries.

Contributors

F C Barros and C G Victora had the original idea, were responsible for the three birth cohort studies of Pelotas, analysed the database and wrote the draft paper. A J D Barros and I S Santos were responsible for the 2004 birth cohort study, analysed the data and collaborated in the writing up of the paper. I S Santos also conducted a qualitative study of the neonatal units. E Albernaz participated in the fieldwork of the 1993 and 2004 birth cohort study and data analysis. A Matijasevich, M R Domingues, I Sclowitz, P C Hallal, and M F Silveira contributed with ideas for the paper and helped in the field work of the 2004 study and data analysis. J Patrick Vaughan participated in the birth cohort studies of 1982 and 1993 and contributed with ideas for the paper. The article was revised and approved by all contributors.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

The 1982 Pelotas Birth Cohort study was financed by the International Development Research Centre, Canada; the 1993 study was financed by the European Union and the Fundação de Amparo à Pesquisa do Rio Grande do Sul, Brazil; the 2004 study was financed by the Division of Child and Adolescent Health and Development of WHO, by the Conselho Nacional de Desenvolvimento Científico e Tecnológico, Brazil, and by the Pastoral da Criança (Catholic non-governmental organisation, Curitiba, Brazil). The Wellcome Trust supported the analyses of the 1982 and 1993 cohort studies. We thank our colleagues Michael S Kramer, Danilo Rolim de Moura, and Simon Halpern, for helpful suggestions for the 2004 Birth Cohort Study, and Elaine Tomasi for providing the information on registered deaths.

References

1 Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? *Lancet* 2003; **361:** 2226–34.
2 State of the world's newborns. A report from saving newborn's lives. Washington, DC: Save the Children, 2001. http://www.savethechildren.org/publications/newborns_report.pdf (accessed Sept 15, 2004).
3 World Bank Group. Data & Statistics. Country classification. http://www.worldbank.org/data/countryclass/countryclass.html (accessed Sept 22, 2004).
4 UNICEF. The state of the world's children 2003. New York: UNICEF, 2004.
5 Victora CG, Barros FC. Infant mortality due to perinatal causes in Brazil: trends, regional patterns and possible interventions. *São Paulo Med J* 2001; **119:** 33–42.
6 Confidential Enquiry into Maternal and Child Health. Stillbirths, neonatal and post-neonatal mortality 2000–2002. England, Wales and Northern Ireland. London: Maternal and Child Health Research Consortium. http://www.cemach.org.uk/publications.htm (accessed Oct 5, 2004).
7 Ministério da Saúde. Manual dos Comitês de prevenção do óbito infantil e fetal. Brasília, Brasil, 2004.
8 Ministério da Saúde. Saúde Brasil 2004. Uma análise da situação de saúde. Brasília, Brasil, 2004: 78.
9 Victora CG, Barros FC, Tomasi E, et al. Tendências e diferenciais na saúde materno-infantil: delineamento e metodologia das coortes de 1982 e 1993 de mães e crianças de Pelotas, RS. *Cad Saúde Pública* 1996; **12** (suppl 1): 7–14.
10 Barros FC, Victora CG, Vaughan JP, et al. The epidemiological transition in maternal and child health in a Brazilian city, 1982–1993: a comparison of two population-based cohorts. *Paediatr Perinat Epidemiol* 2001; **15:** 4–11.
11 Kramer MS, Platt RW, Wen SW, et al. A new and improved population-based Canadian reference for birth weight for gestational age. *Pediatrics* 2001; **108:** e35.
12 Joseph KS, Kramer MS, Allen AC, Mery LS, Platt RW, Wen SW. Implausible birth weight for gestational age. *Am J Epidemiol* 2001; **153:** 110–13.
13 Dubowitz LMS, Dubowitz V, Goldberg C. Clinical assessment of gestational age in the newborn infant. *J Pediatr* 1970; **77:** 1–10.
14 Menezes AMB, Victora CG, Barros FC, et al. Estudo populacional da investigação de óbitos perinatais e infantis: metodologia validade do diagnóstico e sub-registro. *J Pediatr (Rio J)* 1997; **73:** 383–87.
15 Kramer MS. Determinants of low birth weight: methodological assessment and meta-analysis. *Bull World Health Organ* 1987; **65:** 663–737.
16 Guyer B, Strobino DM, Ventura SJ, Singh GK. Annual Summary of Vital Statistics—1994. *Pediatrics* 1995; **96:** 1029–39.
17 Horta BL, Barros FC, Halpern R, Victora CG. Baixo peso ao nascer em duas coortes de base populacional no sul do Brasil. *Cad Saúde Pública* 1996; **12** (suppl 1): 27–31.
18 Bettiol H, Rona RJ, Chinn S, Goldani M, Barbieri MA. Factors associated with preterm births in Southeast Brazil: a comparison of two birth cohorts born 15 years apart. *Paediat Perinat Epidemiol* 2000; **14:** 30–38.
19 Victora CG, Grassi PR, Schmidt AM. Situação de saúde da criança gaúcha, 1980–92: tendências temporais e distribuição espacial. *Rev Saúde Pública* 1994; **28:** 423–32.
20 Kramer MS, Victora CG. Low birthweight and perinatal mortality. In: Semba RS, Bloem M, eds. Nutrition and health in developing countries. Humana, IL: Humana Press, 2000; 57–69.
21 Bricker L, Neilson JP. Routine ultrasound in late pregnancy (after 24 weeks gestation). *Cochrane Database Syst Rev* 2000; **2:** CD001451.

22 Silveira DS, Santos IS, Costa JSD. Atenção pré-natal na rede básica: uma avaliação da estrutura e do processo. *Cad Saúde Pública* 2001; **17:** 131–39.

23 Ministério da Saúde. Assistência pré-natal. Normas e manuais técnicos. Brasília: Ministério da Saúde, 2000.

24 Barros FC, Vaughan JP, Victora CG, Huttly SR. Epidemic of caesarean sections in Brazil. *Lancet* 1991; **338:** 167–69.

25 Behague DB, Victora CG, Barros FC. Consumer demand for caesarean section deliveries in Brazil: informed decision-making, patient choice or social inequality? A population-based birth cohort study linking ethnographic and epidemiological methods. *BMJ* 2002; **324:** 942–47.

26 Potter JE, Berquo E, Perpetuo IH, et al. Unwanted caesarean sections among public and private patients in Brazil: prospective study. *BMJ* 2001; **323:** 1155–58.

27 Joseph KS, Demissie K, Kramer MS. Obstetric interventions, stillbirth, and preterm births. *Semin Perinatol* 2002; **26:** 250–59.

28 Joseph KS, Kramer MS, Marcoux S, et al. Determinants of preterm birth rates in Canada from 1981 through 1983 and from 1992 through 1994. *N Engl J Med* 1998; **339:** 1434–39.

29 Arias E, MacDorman MF, Strobino DM, Guyer B. Annual summary of vital statistics—2002. *Pediatrics* 2003; **112:** 1215–30.

30 Demissie K, Rhoads GG, Ananth CV, et al. Trends in preterm birth and neonatal mortality among blacks and whites in the United States from 1989 to 1997. *Am J Epidemiol* 2001; **154:** 307–15.

31 Silva AAM, Barbieri MA, Bettiol H, Goldani MZ, Rona RJ. Can we explain why Brazilian babies are becoming lighter? *Int J Epidemiol* 2004; **33:** 821–28.

32 Yang H, Kramer MS, Platt RW, et al. How does early ultrasound scan estimation of gestational age lead to higher rates of preterm birth? *Am J Obstet Gynecol* 2002; **186:** 433–37.

33 Victora CG, Vaughan JP, Barros FC, Silva ACS, Tomasi E. How can we explain trends in inequities? Evidence from Brazilian child health studies. *Lancet* 2000; **356:** 1093–98.

34 Brugha R, Pritze-Aliassime S. Promoting safe motherhood through the private sector in low- and middle-income countries. *Bull World Health Organ* 2003; **81:** 8616–23.

35 World Bank Group. Health Nutrition and Population. Child health and the private sector. http://www1.worldbank.org/hnp/CHPS/chpsindex.asp (accessed Sept 22, 2004).