

Cesarean Section Rates and Maternal and Neonatal Mortality in Low-, Medium-, and High-Income Countries: An Ecological Study

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ABSTRACT: Background: Cesarean section rates show a wide variation among countries in the world, ranging from 0.4 to 40 percent, and a continuous rise in the trend has been observed in the past 30 years. Our aim was to explore the association of cesarean section rates of different countries with their maternal and neonatal mortality and to test the hypothesis that in low-income countries, increasing cesarean section rates were associated with reductions in both outcomes, whereas in high-income countries, such association did not exist. **Methods:** We performed a cross-sectional multigroup ecological study using data from 119 countries from 1991 to 2003. These countries were classified into 3 categories: low-income (59 countries), medium-income (31 countries), and high-income (29 countries) countries according to an international classification. We assessed the ecological association between national cesarean section rates and maternal and neonatal mortality by fitting multiple linear regression models. **Results:** Median cesarean section rates were lower in low-income than in medium- and high-income countries. Seventy-six percent of the low-income countries, 16 percent of the medium-income countries, and 3 percent of high-income countries showed cesarean section rates between 0 and 10 percent. Three percent of low-income countries, 36 percent of medium-income countries, and 31 percent of high-income countries showed cesarean section rates above 20 percent. In low-income countries, a negative and statistically significant linear correlation was observed between cesarean section rates and neonatal mortality and between cesarean section rates and maternal mortality. No association was observed in medium- and high-income countries for either neonatal mortality or maternal mortality. **Conclusions:** No association between cesarean section rates and maternal or neonatal mortality was shown in medium- and high-income countries. Thus, it becomes relevant for future good-quality research to assess the effect of the high figures of cesarean section rates on maternal and neonatal morbidity. For low-income countries, and on confirmation by further research, making cesarean section available for high-risk pregnancies could contribute to improve maternal and neonatal outcomes, whereas a system of care with cesarean section rates below 10 percent would be unlikely to cover their needs. (BIRTH 33:4 December 2006)

Key words: cesarean section, maternal mortality, infant mortality, newborn, morbidity

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Cesarean section rates show a wide variation among countries in the world, ranging from 0.4 to 40 percent, and a continuous rise in the trend has been observed in the past 30 years (1). Several attempts have been made to define the most appropriate cesarean section figures at country level, using different conceptual approaches and methodologies (2–6). The most known recommended figure is the 15 percent upper limit suggested by the World Health Organization (WHO) in 1985 (2). This recommendation was based on the cesarean section rates of the countries that had the lowest maternal and neonatal mortality rates in the world at that moment (approximately 10%). Since those were developed countries, WHO increased the recommended cesarean section rate to 15 percent, taking into consideration that developing countries had a larger proportion of population at risk that could benefit from cesarean section.

Although the figure was estimated arbitrarily, the 2 main concepts behind the recommendation are relevant. First, appropriate cesarean section rates should be defined through an outcome-based approach. Cesarean section is a surgical intervention to prevent or treat life-threatening maternal or perinatal complications, and the appropriate rate of use should be one associated with the lowest attainable level of maternal and perinatal morbidity and mortality. The few published studies that have explored this approach have been conducted in developed countries and have found either no association between cesarean section rates and health outcomes (3) or small associations restricted to specific subgroups (5). As far as we know, no relevant studies assess the effects or the association of different cesarean section rates and health outcomes in international comparisons including developed and developing countries.

Second, appropriate cesarean section rates could differ among populations. The higher the prevalence of a high-risk population, the higher the need of cesarean section to prevent or treat pregnancy complications might be. Several studies on cesarean section determinants and effects have considered this fact and have adjusted their results according to the population case mix, but again, not in international comparisons (7).

Our aim in this ecological study was to explore the association of cesarean section rates of different countries with their maternal and neonatal mortality rates and to test the hypothesis that in low-income countries, increasing cesarean section rates are associated with reductions in both outcomes, whereas in high-income countries, such an association does not exist. This analysis could contribute to the global health community discussion about appropriate cesarean

section rates, as well as to the conceptual framework to analyze the controversy.

Methods

We conducted a multigroup ecological study and based our conceptual framework and hypothesis on the following assumptions.

1. A cesarean section rate is actually a summary measure of the rate of cesarean section administered to prevent or treat pregnancy complications in specific, high-risk subpopulations (medically justified cesarean section) plus the rate of cesarean section administered to a low-risk subpopulation (medically unjustified cesarean section).
2. Cesarean section is an effective intervention to reduce maternal and neonatal mortality, compared with vaginal delivery, when it is medically justified. This assumption is supported by a few experimental studies, as well as several observational research studies (8–12).
3. Cesarean section is an ineffective intervention to reduce maternal and neonatal mortality, compared with vaginal delivery, when it is medically unjustified. This assumption is supported by the lack of experimental studies comparing cesarean section and vaginal delivery in healthy pregnancies and by extensive published observational evidence. Moreover, this observational evidence shows that unjustified cesarean section can even be harmful to women and children (11).
4. Low-income countries are likely to have a lower number of medically justified cesarean sections than necessary to treat their at-risk population. On the other hand, the number of medically unjustified cesarean sections on healthy pregnancies is extremely low and restricted to small subgroups of high-income people. Increasing cesarean section rates in these countries would then be associated with a reduction in maternal and neonatal mortality. This assumption is based on published observational studies that reported the lack of necessary cesarean section in low-income countries (12–15) and on the fact that most deliveries are attended in the public sector, which has an extremely low frequency of cesarean section on demand.
5. High-income countries are likely to perform the necessary number of medically justified cesarean sections in the population at risk. Therefore, increasing cesarean section rates in these countries would mean that unjustified cesarean section in healthy pregnancies is taking place, without a further reduction in maternal and neonatal mortality.

This assumption is based on observational studies showing the lack of association between cesarean section rates and health outcomes in developed countries (3,16).

Sources of Data

We obtained information about cesarean section rates for different countries from several data sources: (1) national reports from government health offices derived from routine statistical surveillance or national surveys (17,18); (2) the World Health Organization (WHO) report for 2005 (19); (3) published journal articles that reported the incidence of cesarean sections in countries at a national level, in a search conducted on MEDLINE, EMBASE, POPLINE, and LILACS, since 1990 (1,20–24), and reference lists of articles retrieved; and (4) data from the Demographic and Health Surveys Program, which were retrieved from surveys made since 1990 (25). The Demographic and Health Surveys collect information on several reproductive health topics. Surveys are implemented by institutions in the host country, usually government statistical offices, and 5,000–30,000 women of childbearing age are interviewed in a standard survey. When possible, we used the reported national cesarean section rate for 2000 or 2001 for all countries, to be consistent with the neonatal and maternal mortality data. Demographic and Health Surveys figures are considered valid estimations of

actual cesarean section rates, although they might be imprecise (26).

Maternal mortality ratios, early neonatal mortality rates, annual numbers of births, proportions of skilled attendant deliveries, and proportions of literate population were extracted from the WHO 2005 report, which shows data for the year 2000. Early neonatal mortality is not directly reported by all countries, and some figures in the WHO report are based on estimation methods. Gross national income per capita was extracted from World Bank data for the year 2004 (27). For some countries, the gross national income was not available and was replaced by the gross domestic product per capita (28).

Readers are referred to information about supplementary material on cesarean section rates, mortality rates, and other sociodemographic and health data by country (see “Supplementary Material” section).

Statistical Analysis

We used the median and interquartile range as summary measures for exposures and outcomes. We arbitrarily classified cesarean section rates into 3 categories (0–10.0%, 10.1–20.0%, and >20%) and reported country median maternal and neonatal mortality rates according to each category. Countries were classified into 3 categories, low-, medium-, and high-income countries, according to the classification of the International Union for the Scientific Study of

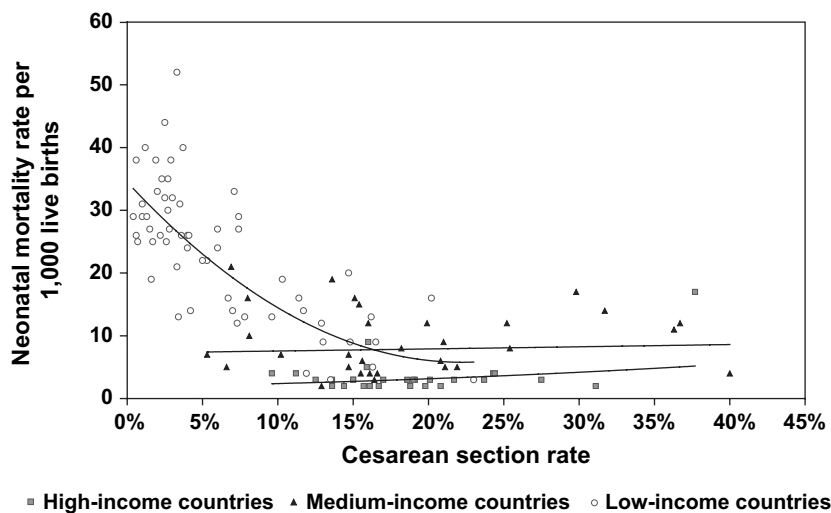


Fig. 1. Association between cesarean section rates and neonatal mortality in 119 countries of the world. A significant association between these 2 variables was seen in low-income countries ($r = 0.775$; $n = 59$, $p < 0.0001$), whereas no significant association was seen in high- and medium-income countries ($r = 0.354$; $n = 29$, $p = 0.060$, and $r = 0.063$; $n = 31$, $p = 0.731$, respectively). Fitted values for low-income countries: $\exp(3.565 - 8.895 \times \text{cesarean section})$. Fitted values for medium-income countries: $\exp(1.982 + 0.427 \times \text{cesarean section})$. Fitted values for high-income countries: $\exp(0.585 + 2.813 \times \text{cesarean section})$.

Table 1. Number of Countries, Births per Year, Neonatal Mortality Rates, and Maternal Mortality Ratios According to Categories of Cesarean Section Rates and Level of Country Income

Cesarean Section Rate (%)	Countries (n = 119)						Early Neonatal Mortality Rate (per 1,000 Live Births)			Maternal Mortality Ratio (per 100,000 Live Births)								
	HI		MI		LI		HI		MI		LI		HI		MI		LI	
	No. (%)	No. of Births*	No. (%)	No. of Births	No. (%)	No. of Births	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	Median (IQ Range)	
0-10.0	1 (3.4)	54	5 (16.4)	893	45 (76.3)	69,687†	4.0 (4.0-4.0)	10.0 (6.0-18.5)	27.0 (23.0-32.5)	54.0 (54.0-54.0)	87.0 (17.0-220.0)	630.0 (225.0-1,000)						
10.1-20.0	19 (65.5)	3,115	15 (48.4)	5,530	12 (20.3)	3,731	3.0 (2.0-3.0)	7.0 (4.0-12.0)	10.5 (6.0-15.5)	7.0 (5.0-17.0)	49.0 (23.0-130.0)	117.0 (34.5-237.5)						
More than 20.0	9 (31.1)	5,706†	11 (35.5)	10,202	2 (3.4)	20,137	3.0 (2.5-4.0)	9.0 (5.0-12.0)	9.5 (3.0-16.0)	8.0 (5.5-20.0)‡	82.0 (31.0-130.0)	444.5 (33.0-56.0)						
Total	29 (100)	8,875	31 (100)	16,625	59 (100)	93,555	3.0 (2.0-3.5)	8.0 (5.0-12.0)	25.0 (14.0-31.0)	8.0 (5.0-17.0)	67.0 (27.0-130.0)	480.0 (110.0-850.0)						

*Per 1,000; †data of one country are missing.

IQ = interquartile; HI = high-income countries; MI = medium-income countries; LI = low-income countries.

Population (29). We examined the association between cesarean section rates and maternal and neonatal mortality by fitting multiple linear regression models. The fit of the regression models was ascertained by the examination of residuals. On the original scale, the residuals from the multiple regression models were not normally distributed. This problem was corrected after transforming maternal and neonatal mortality to the log scale.

The interaction between cesarean section rates and country category was assessed by introducing an interaction term in this regression model. We did a multiple linear regression analysis to adjust for gross national income, proportion of skilled attendance deliveries, and proportion of literate population.

Sensitivity analyses were performed to detect potential deviations from the final findings: first, excluding countries with data before 1997 and, second, using infant mortality as a surrogate of neonatal mortality (because the latter was based on estimation methods).

Results

We gathered data on national cesarean section rates, maternal mortality ratios, and early neonatal mortality rates for 119 countries, for the 1991-2003 period. Nearly 80 percent of the figures corresponded to the 1997-2003 period. The median cesarean section rate of the sample was 12.9 percent (range 0.4-40), whereas the median maternal mortality ratio and early neonatal mortality rate were 83.5 per 100,000 live births (range 0-1,800) and 12.0 per 1,000 live births (range 2-52), respectively.

The number of countries, births per year, neonatal mortality rates, and maternal mortality ratios according to categories of cesarean section rates and level of country income are shown in Table 1. It can be observed that 76 percent of the low-income and 16 percent of medium-income countries showed cesarean section rates between 0 and 10 percent, whereas only 1 (3%) high-income country presented rates within that category. On the other hand, whereas only 3 percent of low-income countries showed cesarean section rates above 20 percent, 36 and 31 percent of medium- and high-income countries, respectively, showed rates above that figure. The median cesarean section rates with interquartile ranges in parentheses were 4.0 percent (2.3-9.6%), 16.1 percent (13.6-21.9%), and 17.0 percent (15.0-21.3%) for the low-, medium-, and high-income countries, respectively.

A statistically significant interaction was shown between cesarean section rates and the country income category with respect to an association with maternal mortality ratios ($F_{2,112} = 15.199; p < 0.0001$)

and with early neonatal mortality rates ($F_{2,113} = 26.704$; $p < 0.0001$). The data analyses were therefore performed separately for low-, medium-, and high-income countries.

Cesarean Section Rates and Early Neonatal Mortality

In the regression analysis, a negative and statistically significant linear correlation was observed between cesarean section rates and neonatal mortality (in log scale) in low-income countries ($r = 0.775$; $n = 59$, $\beta = -8.895$, $CI_{\beta} = [-10.819, -6.971]$, $p < 0.0001$). No association was observed in medium-income countries ($r = 0.063$; $n = 31$, $\beta = 0.427$, $CI_{\beta} = [-2.088, 2.941]$, $p = 0.731$), and a positive and borderline statistically significant linear correlation was observed in high-income countries ($r = 0.354$; $n = 29$, $\beta = 2.813$, $CI_{\beta} = [-0.124, 5.751]$, $p = 0.060$) (Fig. 1). This finding was influenced by South Korea, which is an outlier (cesarean section rate 37%, early neonatal mortality rate 17 per 1,000). Excluding South Korea from the analysis, the p value goes up to 0.587. The observed association in low-income countries remained after adjusting for gross national income, proportion of skilled attendance deliveries, and proportion of literate population ($r = 0.843$; $n = 59$, $\beta = -5.678$, $CI_{\beta} = [-8.018, -3.338]$, $p < 0.0001$).

Sensitivity analyses restricting the data to the period 1997–2003 and modeling infant mortality as

the dependent variable showed similar results (data not shown).

Cesarean Section Rates and Maternal Mortality

A negative and statistically significant linear correlation was observed between cesarean section rates and maternal mortality in low-income countries ($r = 0.610$; $n = 59$, $\beta = -14.811$, $CI_{\beta} = [-19.923, -9.700]$, $p < 0.0001$). No association was observed in medium- and high-income countries ($r = 0.207$; $n = 31$, $\beta = 2.500$, $CI_{\beta} = [-1.961, 6.960]$, $p = 0.261$, and $r = 0.114$; $n = 28$, $\beta = 1.918$, $CI_{\beta} = [-4.693, 8.529]$, $p = 0.556$, respectively) (Fig. 2). The observed association in low-income countries became not significant after adjusting for gross national income, proportion of skilled attendance deliveries, and proportion of literate population. Sensitivity analyses restricting the data to the period 1997–2003 showed similar results (data not shown).

Discussion and Conclusions

We have shown that the association between cesarean section rates and neonatal and maternal mortality is different among countries. Thus, whereas in low-income countries, as cesarean section rates increase, neonatal and maternal mortality decrease, in medium-

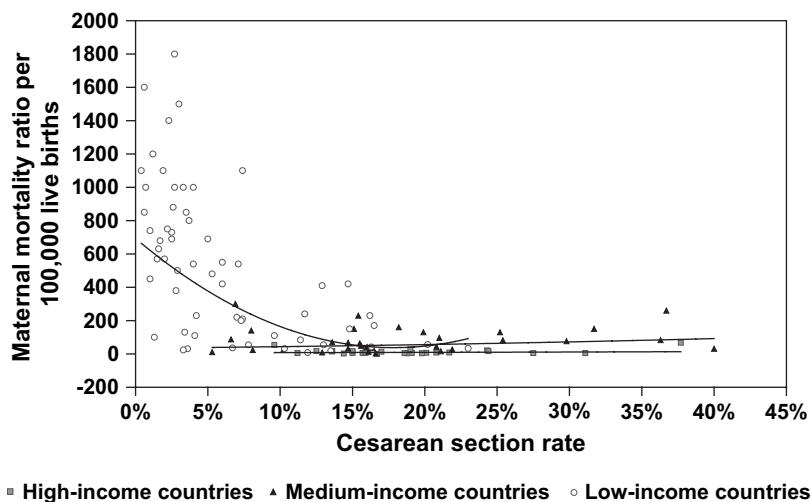


Fig. 2. Association between cesarean section rates and maternal mortality in 118 countries of the world. A significant association between these 2 variables was seen in low-income countries ($r = 0.610$; $n = 59$, $p < 0.0001$), whereas no significant association was seen in high- and medium-income countries ($r = 0.114$; $n = 28$, $p = 0.556$, and $r = 0.207$; $n = 31$, $p = 0.261$). Fitted values for low-income countries: $\exp(6.617 - 14.811 \times \text{cesarean section})$. Fitted values for medium-income countries: $\exp(3.525 + 2.500 \times \text{cesarean section})$. Fitted values for high-income countries: $\exp(1.861 + 1.918 \times \text{cesarean section})$.

and high-income countries, the increase in cesarean section rates is not associated with significant changes in mortality rates. Our arbitrary 10 percent cesarean section rate threshold seems to have particular implications: 76 percent of low-income countries had cesarean section rates less than or equal to that figure; these countries showed a neonatal mortality more than 2 times higher and a maternal mortality more than 5 times higher than countries with cesarean section rates above 10 percent. On the other hand, approximately 97 percent of the high-income countries had cesarean section rates above 10 percent; these countries showed more similar maternal and neonatal mortality rates among them.

One possible explanation for these findings was postulated in our conceptual framework. In many low-income countries fewer cesarean sections would be performed than those needed for their population at risk. On the other hand, in most high-income countries the necessary number of cesarean sections would be performed for their population at risk, and their higher rates could be a measure of the use of unjustified cesarean sections in healthy populations and the use of cesarean section to prevent nonsevere morbidity. Although these mechanisms cannot be proved in this kind of study, they are supported by previous observational studies and clinical thinking and certainly deserve further exploration.

This study has several strengths. The ecological design is the appropriate research design to assess the association of cesarean section rates with health outcomes at the population level among different countries (30). We were able to retrieve cesarean section and mortality figures from 119 countries (54% of the 219 United Nations country members, representing 90% of the world annual number of births), and the median gross national income of our sample was close to that of all the United Nations countries (US\$6,510 and US\$5,770, respectively).

Although low-income countries could be less represented in our sample than medium- and high-income countries, it seems unlikely that the association between cesarean section rates and maternal and neonatal mortality would be different if we could include them all. The data came primarily from publicly available sources, and no country that presented cesarean section and mortality data was excluded from analysis; thus, no selection bias was introduced by the research team.

Nevertheless, the study has several limitations related to the research design as well as to the data quality that cannot be excluded as possible alternative explanations of the findings. Misclassification of exposure or outcome data, even nondifferential, can

be a source of bias in ecological designs that may increase the associations (31). Furthermore, the validity of the analyses presented is crucially dependent on the extent to which the data on neonatal mortality, infant mortality, maternal mortality, and, more specifically, cesarean section rates are representative of the country to which they refer (30,32). In this study, misclassification of both cesarean section and mortality rates was more likely to occur in low-income countries, in which 36 percent of the maternal mortality ratios came from estimations and 68 percent of the cesarean section rates came from surveys, compared with 19 and 19 percent in medium-income and 3 and 0 percent in high-income countries. For neonatal mortality, the sensitivity analysis that used infant mortality as an outcome (a better-quality recorded outcome) showed similar results, thus supporting the suggestion that the influence of misclassification on the neonatal findings could not have been relevant. Nevertheless, we cannot exclude the possibility that the negative association between cesarean section rates and maternal and neonatal mortality observed in low-income countries may be actually smaller. On the other hand, it is less likely that misclassification could have affected results in high-income countries as their data quality is much better and no association between cesarean section rates and mortality was actually found.

Confounding can be a major problem in international ecological comparisons, as the correlation of confounders among countries is usually higher than that in individual studies, and difficult to disentangle (32). It is likely that in low-income countries, cesarean section rates are highly correlated with availability of health care services and actual provision of health care to the population, which are the main determinants of health outcomes. We have controlled the confounding effect of those determinants adjusting the analysis by the countries' gross national income and the proportion of skilled attendance deliveries as proxy measures of the above-mentioned determinants. Nevertheless, we cannot rule out that residual confounding could be partially responsible for the findings in low-income countries, but it is less likely that it could have occurred in high-income countries, in which those health determinants are much more homogeneously distributed.

Another potential confounder is the health status of pregnant women, which is both a determinant of the need for medically justified cesarean sections and of health outcomes. We had the limitation that there were no country direct measurements of their population "case mix" (3). We had to use literacy and gross national income as proxy measures of the population

health risk since both are highly correlated with population risk profile and commonly used for this purpose in research studies (33). As we mentioned above, it is again more likely that the population case mix in high-income countries was more homogeneous than in low-income ones; the proportion of literate populations in medium- and high-income countries showed a range between 76 and 100 percent, while in low-income countries the range was between 18 and 99 percent. This finding implies that the potential confounding effect of population case mix is less likely to have influenced the findings in high-income countries.

Conclusions of this report have limitations inherent to ecological analyses, and no inferences at the individual country level should be made to avoid any kind of ecological fallacy. Nevertheless, 2 similar outcome-based approaches comparing hospital cesarean section rates within a developed country or region have been published (3,5), and our findings in high-income countries are consistent with them.

Our findings should be compared with a WHO international survey conducted in 120 hospitals in 8 Latin American countries (34). The survey collected prospective individual data on all births for a period of 3 months at each hospital and found that increasing rates of cesarean section were positively associated with maternal and neonatal mortality and morbidity, especially above 10 percent. These observations are consistent with our findings in medium-income countries, the country category to which most of the countries surveyed by WHO belong. Future research should focus on confirming the observations made in low- and high-income countries.

In conclusion, in medium- and high-income countries, we found no association between cesarean section rates and maternal or neonatal mortality. Thus, it becomes relevant for future good-quality research to assess the effect of the high figures of cesarean section rates on maternal and neonatal morbidity. For low-income countries and after confirmation from further research, making cesarean section available for high-risk pregnancies could contribute to improvements in maternal and neonatal outcomes, whereas a system of care with cesarean section rates below 10 percent would be unlikely to cover their needs.

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Supplementary Material

Supplementary Table S1 displaying cesarean section rates, mortality rates, and other sociodemographic and health data by country, as found in the corresponding sources, is available as part of the online article from <http://www.blackwell-synergy.com>.

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