Rates of caesarean section: analysis of global, regional and national estimates

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Summary

Rates of caesarean section are of concern in both developed and developing countries. We set out to estimate the proportion of births by caesarean section (CS) at national, regional and global levels, describe regional and subregional patterns and correlate rates with other reproductive health indicators. We analysed nationally representative data available from surveys or vital registration systems on the proportion of births by CS. We used local non-parametric regression techniques to correlate CS with maternal mortality ratio, infant and neonatal mortality rates, and the proportion of births attended by skilled health personnel. Although very unevenly distributed, 15% of births worldwide occur by CS. Latin America and the Caribbean shows the highest rate (29.2%), and Africa shows the lowest (3.5%). In developed countries, the proportion of caesarean births is 21.1% whereas in least developed countries only 2% of deliveries are by CS. The analysis suggests a strong inverse association between caesarean section rates and maternal, infant and neonatal mortality in countries with high mortality levels. There is some suggestion

of a direct association at lower levels of mortality. CS levels may respond primarily to economic determinants.

Introduction

In 1985 the World Health Organization stated: "There is no justification for any region to have caesarean section (CS) rates higher than 10–15%".[1] Two decades later, however, the optimal rate of births by CS remains controversial in both developing and developed countries.[2-4] In many developed countries, CS rates have increased, and attention has focused on strategies to reduce use due to concern that higher CS rates do not confer additional health gain but may increase maternal risks, have implications for future pregnancies and have resource implications for health services.[5;6] In developing countries, on the other hand, lack of availability of or access to maternal health services and the corresponding underuse of CS are part of a web of factors predisposing to high maternal and perinatal mortality.[7]

We set out to compile available CS rates by country and to calculate regional and global estimates of the proportion of caesarean deliveries so as to establish an epidemiological basis for global and regional needs assessment and further public health research and action. Furthermore, we correlate CS rates with maternal, infant and neonatal mortality, and with the proportion of births attended by skilled health personnel to assess ecologic associations.

Methods

The CS rate is usually defined as the number of caesarean deliveries over the total number of live births, and is usually expressed as a percentage. CS rates were

obtained from nationally representative surveys and from vital registration reports or from health authorities.

For developing countries, 53 identified surveys were undertaken by the Demographic and Health Surveys (DHS) programme, which represents the largest worldwide effort to obtain demographic and health data from nationally representative household surveys in developing countries (www.measuredhs.com). As the DHS use standardized questionnaires and methods of training, data collection and data processing, they are often considered the "best available gold standard" for many types of health indicator in developing countries.[8] DHS figures on CS rates refer to children born in the three years previous to the survey exercise. Data were collected through interviews in which mothers are asked: "was (name) delivered normally or by caesarean?" For countries with more than one available DHS survey, the most recent was used.

For developed countries, estimates based on published vital statistics from the most recent year available were used. For 34 European countries, data were obtained from the European Health for All Database (www.who.dk), maintained by the WHO European Regional Office, which includes basic demographic, socio-economic and health-related indicators. Health for All data are derived from routine national registration activities.

For 39 countries, mainly in the developing world, for which one of the above-mentioned sources was not available, a search was made of electronic publication databases, web search engines and government web sites. For example, the health services of United States, Canada, Australia and New Zealand issue regular publications and maintain web pages with up-to-date information on maternal health indicators. If such efforts failed, however, an attempt was made to contact the relevant health authorities (for example, in Thailand, Papua New Guinea, Botswana, Cuba and Fiji). As population-representative data for China could not be obtained, we reviewed available published information on subnational CS rates and calculated the average.

Some countries report CS rates in terms of proportion of total deliveries rather than live births and no attempt was made in this analysis to adjust for multiple pregnancies. The Annex presents a comprehensive list of countries for which data were identified as of March 2005, and for each country, the proportion of caesarean deliveries, the data source and the year to which the data refer.

For regional and subregional averages, countries were grouped according to the United Nations' classification.[9] Estimates were calculated as weighted means, with weights the country's share of live births in the region. Regional and subregional coverage was calculated as the proportion of total regional and subregional live births for which nationally representative data on CS were available. As discussed below, data for

China (representing approximately 15% of global live births in 2002) are not nationally representative but were included in coverage calculations where noted.

We correlated CS rates with maternal mortality ratios (maternal deaths per 100 000 live births),[10] infant mortality rates (infant deaths per 1000 live births),[11] neonatal mortality rates (neonatal deaths per 1000 live births),[12] and rates of skilled birth attendant (%)[13] by transforming the variables to log scale and applying local non-parametric regression techniques (lowess plots) to identify patterns in the data without assuming a particular functional form.[14]

Regional and subregional estimates were calculated with Microsoft Excel 2003. Other statistical analyses were done and graphs were prepared using Stata 8.2.

Results

Coverage of estimates

Data were available for 126 countries, representing nearly 89% (74% excluding China) of global live births in 2002 (Table 1). At regional level, coverage ranged from 83% in Africa to 100% in Northern America. Coverage at subregional level was high except for Middle Africa, where estimates represent only 26% of live births in 2002 (data not obtained for Angola, Congo, Democratic Republic of the Congo and Equatorial Guinea).

Rates of CS worldwide

The global rate of CS is estimated here as 15% (Table 1). Rates are higher in developed countries and in Latin America and the Caribbean, but lower in other developing countries. The average rate of CS deliveries is 3.5% in Africa, with highest rates in South Africa (15.4%), Egypt (11.4%) and Tunisia (8%). Chad (0.4%), Madagascar, Niger and Ethiopia (0.6%) show the lowest CS rates in the world. Central African Republic, Burkina Faso, Mali and Nigeria all show CS rates below 2%.

The average CS rate in Asia is 15.9%. China, Hong Kong and Lebanon present the highest CS rates in Asia, with estimates of 40.5%, 27.4% and 23.3%, respectively. Nepal and Cambodia's rates are lowest (1%), followed by Yemen (1.5%). In Europe, the average rate of CS deliveries is 19%, with highest rates in Italy (36%) and Portugal (30.2%), and lowest rates in Serbia and Montenegro (8%) and Moldova (6.2%). The region Latin America and the Caribbean shows an average CS rate of 29.2%, with national rates ranging from 1.7% in Haiti and 7.9% in Honduras to 39.1%, 36.7%, 31.3% and 30.7% in Mexico, Brazil, the Dominican Republic and Chile, respectively.

In more developed regions (including Europe, Northern America, Japan, Australia and New Zealand) rates range between 6.2% and 36%, with an average of 21.1%. In less developed regions (Africa, Asia excluding Japan, Central and South America, and Oceania excluding Australia and New Zealand), variation is marked, ranging from 29.2% in Latin America and the Caribbean to 3.5% in Africa; the

average rate is 14.3%. In least developed countries (49 countries mostly in Africa), CS rates range from 0.4% in Chad to 6% in Cape Verde, with an average rate of 2%.

Figure 1 shows dotplots, with median and interquartile range, of national CS rates by region, in both log (upper panel) and natural scale (lower panel). Displaying CS rates in log scale highlights countries with low rates. All except two African countries are below the recommended range whereas in Europe, Northern America and Latin America and the Caribbean most countries are above the recommended maximum. The same data plotted in natural scale (lower panel) highlight countries with high rates. In both panels, outliers have been labeled.

CS rates and other reproductive health indicators

Figure 2 shows on log-log scale a plot of CS rates versus maternal mortality, with selected countries identified. There is a clear inverse association between maternal mortality and CS rates over nearly the whole range of observed mortality, although the strength of the association weakens with decreasing maternal mortality ratio. The local regression suggests four piece-wise linear segments of differing slope, with the segment at lowest maternal mortality (with positive slope) showing a direct, rather than inverse, relationship at very low levels of mortality. The finding of progressively increasing slope from highest to lowest levels of mortality (from more to less negative, with a positive slope at lowest mortality rates) is robust to changes in local regression bandwidth from 0.35 to 0.70. A similar pattern is found when plotting CS rates versus infant or neonatal

mortality, suggesting that it is a fundamental feature of the observed data on CS (results not shown).

Nationally representative data were not obtained for China. However, a review of recent studies yielded 11 reports of CS rates from different areas (Table 2).[15-25] Nowhere were observed rates below 22.5%, and in one site the reported rate was 63.2%. The unweighted mean of this convenience sample is 40.5%, and is virtually unchanged ignoring extreme values (22.5%, 63.2%). In Figure 2, the vertical bar through data markers displaying the unweighted mean for China shows the full range of variation reported in Table 2. If additional observations from the studies listed in Table 2 are considered, evidence supporting a high national CS rate in China becomes stronger: over the past 25 years, sampled sites have witnessed exponential growth in CS rates, and a simple linear trend of the logged rates predicts a value of 56.3% for 2001 (results not shown), suggesting that the mean of recent observations may well be a conservative estimate for the sample.[15] In sum, only the lowest of recent Chinese observations are close to the average CS rates found in countries with similar levels of mortality (Figure 2). Exclusion of Chinese data from the regression depicted in Figure 2, as well as those reported subsequently, does not change the observed patterns in any respect.

Figure 2 shows strong regional clustering suggesting common regional factors determine both CS and mortality rates. In Africa, almost all countries have low CS and high mortality rates. European countries span both sides of the regression line for the low-mortality section. Australia, New Zealand, United States and Canada follow the

European pattern. Countries in Latin America, with few exceptions, show CS rates above 15%, and even those with lower maternal mortality (e.g. Mexico, Chile) show notably high CS rates compared with countries in the same mortality range from other regions. Asian countries show the least regional clustering. Notable Asian outliers are the Central Asian republics (e.g. Tajikistan, Uzbekistan, Turkmenistan and Azerbaijan), with very low CS rates, and China, with an apparently very high rate.

Figure 3 displays results from local regressions restricted to countries with CS rates above 15%. Although below 15% higher CS rates are unambiguously correlated with lower maternal mortality, above this range, higher CS rates are predominantly correlated with higher maternal mortality. A similar pattern is found for infant and neonatal mortality (results not shown). The stratified analysis therefore supports the suggestion in Figure 2 that, above a certain ceiling, higher CS rates may be associated with poorer outcomes.

CS rates are highly correlated with the proportion of births attended by trained health personnel (Figure 4). With the exception of countries in Latin America, countries with skilled birth attendant rates below 80% consistently show CS rates well below the recommended range of 10−15%. Latin America is unique in presenting several countries (in particular, El Salvador, Paraguay and Ecuador, all with skilled birth attendant rates below 80% and CS rates above 15%) that appear to offer dramatically differing levels of obstetric care to their populations.

Discussion

Since publication of the WHO consensus statement in 1985, debate regarding desirable levels of CS has continued;[2-4] nevertheless, this paper represents the first attempt to provide a global and regional comparative analysis of national rates of caesarean delivery and their ecologic correlation with other indicators of reproductive health. With the exception of Latin American and Caribbean countries, as well as a few countries in Asia, the majority of countries with high mortality rates have CS rates well below the recommended range of 10–15%, and in these countries there appears to be a strong ecologic association between increasing CS rates and decreasing mortality.

Interpretation of the relationship between CS rates and mortality in countries with low mortality rates is more ambiguous; nevertheless, the sum total of the evidence presented here supports the hypothesis that, as has been argued previously,[26] when CS rates rise substantially above 15%, risks to reproductive health outcomes may begin to outweigh benefits. To rebut the argument that this finding is a mere chance disposition of the data, we analysed CS rates versus per-capita national income. CS rates display a broadly similar correlation (albeit with opposite slope) with income per head as with mortality rates. However, here a local regression shows three quasi-linear segments of different slope, with no fourth downturning segment at the highest levels of income (results not shown). Such an S-shaped curve is typical of many classes of growth systems and suggests that CS rates in fact respond primarily to economic determinants, initially increasing slowly at low income, then increasing more rapidly at intermediate income and finally increasing more slowly again as saturation levels of CS are gradually

approached at higher levels of income. Although income and mortality show an

unambiguously strong linear correlation in log scale, even at very high levels of income

there is no suggestion of opposite sign in the plot of income versus CS rates, the contrary

of what would be expected if the downturning segment in Figure 2 were merely a chance

occurrence.

In many developed countries, CS rates have been steadily increasing over the last

decade.[27;28] For example, preliminary data for 2003 in the United States suggest that the

CS rate has risen for the seventh straight year, to 27.6%.[28] Given levels of utilization of

surgical procedures unprecedented in the history of modern obstetric care, it is

increasingly important to evaluate the corresponding experience with maternal and

newborn health outcomes. According to data from the United Kingdom Confidential

Enquiry into Maternal Deaths, an elective CS with no emergency presents a 2.84 times

greater chance of maternal death than a vaginal birth,[29] suggesting that, when population

CS rates rise beyond medically necessary levels, risks may outweigh benefits. Thus, high

CS rates may be an indicator for excess maternal mortality in developed countries.[26]

However, in order to conclusively evaluate the relationship between reproductive

mortality and high CS rates, developed countries will need to reinforce their monitoring

strategies and more detailed individual-level analyses will need to be performed.

On the other hand, in countries designated by the United Nations as least

developed,[9] uniformly low CS rates and high levels of maternal, infant and neonatal

mortality are observed. In these 49 countries (34 of which are in Africa), the average CS rate is only 2%, indicating a clear need to improve access to surgical obstetric care.

Outliers in Figures 1 and 2 suggest countries that may be facing unique problems relative to their regional counterparts. For example, in countries with relatively low mortality where CS rates remain substantially below the reference range (e.g. Azerbaijan, Tajikistan, Turkmenistan, Uzbekistan) policy makers may wish to investigate whether systemic obstacles or bottlenecks impede delivery of the procedure when medically necessary. Conversely, policy makers in countries with relatively high mortality but where CS rates are sharply above the reference range (e.g. Brazil, Dominican Republic, Mexico) or where other reproductive health system indicators offer reasons for concern (e.g. El Salvador, Paraguay, Ecuador), may want to investigate whether their health systems are delivering medically appropriate obstetric care and to prioritize a monitoring strategy for CS rates and reproductive mortality.

The proportion of births by CS has been proposed as a proxy indicator for measuring access, availability or appropriateness of medical care, as well as for monitoring changes in maternal mortality in developing countries.[30] The strength of the correlation in the high mortality region of Figure 2 would, with the above-noted qualifications, support these claims. Moreover, while measuring progress towards the Millennium Development Goals (www.developmentgoals.org) for reproductive health lags, CS rates (especially in conjunction with other indicators) may provide a valuable proxy indicator. Information on CS is relatively easy to collect by surveys since mothers

can be expected to remember more reliably the type of delivery than, for example, who attended the birth, the number of antenatal care visits, or the antenatal tests performed.[31] Moreover, where data are available, subnational differences (e.g. urban and rural) suggest health inequalities. For example, in Bangladesh, the proportion of deliveries by CS is 10.5% in urban areas but only 1.7% in rural areas according to the demographic and health survey in 2004.

Skilled birth attendant rates are conventionally used as a process indicator for maternal mortality, an interpretation that would seem to have greater validity for less and least developed countries, since, when rates of skilled birth attendant are high, they are no longer a sensitive indicator for the availability of surgical obstetric care (refer Figure 4). While both measures can serve as access indicators, each refers to a distinct level of services.

The limitations of ecological analysis must be kept in mind: the validity of inferences regarding a causal association between CS rates and reproductive health outcomes depends on the absence of uncontrolled factors and interactions, a condition which is almost surely not met here. For example, based on this analysis, it is impossible to exclude that rising CS rates are mirroring a change in the demographic risk profile of pregnant women (e.g older primiparae, different obesity levels or other medical disorders).

Moreover, a number of large countries remain without national data on CS, especially in Western Asia (Iraq and Syria) and Middle Africa (Angola, Congo, Democratic Republic of the Congo). Although all available information supports the conclusion of high current rates of CS in China,[15] substantial uncertainty surrounds our provisional estimate of 40.5%, and would be substantially mitigated only by more data on rural rates of CS in that country (refer Table 2).

This global and regional overview of CS rates establishes a comparative basis for the investigation of country-specific determinants. It also provides a first step supporting an evidence-based needs assessment in surgical obstetric care and highlights a number of hypotheses that warrant more detailed research.

Conflict of interest (including financial interest)

None

Authors' contributions

APB, MM and JAL contributed equally. APB and MM conceived of the study, compiled the data and participated in all the analyses. JAL designed and executed the exploratory and statistical analyses. APB, MM and JAL drafted the manuscript. WB provided key input and interpretations regarding China. APB, MM, JAL, WB, JT, PVL and MW provided key interpretive and critical input and revised the manuscript.

Figures and tables

Table 1: Caesarean section rates by region and subregion and coverage of the estimates (figures in brackets represent coverage excluding data from China).

Region/subregion[a]	Births by caesarean section (%)	Range, minimum to maximum (%)	Coverage of estimates[b] (%)
World total	15.0	0.4-40.5	89 (74)[c]
More developed regions	21.1	6.2-36.0	90
Less developed countries	14.3	0.4-40.5	89 (72)[c]
Least developed countries	2.0	0.4-6.0	74
Africa	**3.5**	**0.4-15.4**	**83**
Eastern Africa	2.3	0.6-7.4	93
Middle Africa	1.8	0.4-6.0	26
Northern Africa	7.6	3.5-11.4	84
Southern Africa	14.5	6.9-15.4	93
Western Africa	1.9	0.6-6.0	95
Asia	**15.9**	**1.0-40.5**	**89 (65)[c]**
Eastern Asia	40.5	27.4-40.5	90 (0.31)[c]
South-Central Asia	5.8	1.0-10.8	93
South-Eastern Asia	6.8	1.0-17.4	83
Western Asia	11.7	1.5-23.3	75
Europe	**19.0**	**6.2-36.0**	**99**
Eastern Europe	15.2	6.2-24.7	100
Northern Europe	20.1	14.9-23.3	100
Southern Europe	24.0	8.0-36.0	97
Western Europe	20.2	13.5-24.3	100
Latin America & the Caribbean	**29.2**	**1.7-39.1**	**92**
Caribbean	18.1	1.7-31.3	78
Central America	31.0	7.9-39.1	98
South America	29.3	12.9-36.7	90
Northern America	**24.3**	**22.5-24.4**	**100**
Oceania	**14.9**	**4.7-21.9**	**92**
Australia/New Zealand	21.6	20.4-21.9	100
Melanesia	4.9	4.7-7.1	87
Micronesia	na[d]	na	0
Polynesia	na	na	0

[a] Countries categorized according to the UN classification. Countries with a population of less than 140 000 in 2000 are not included.

[b] Refers to the proportion of live births for which nationally representative data were available.

[c] Figures in brackets represent coverage excluding data from China.
[d] na = data not available.

Table 2: Caesarean section rates in China.

Source	Year	Place	Sample size	CS (%)
Cai, 1998[15] [a]	1993	Shanghai-urban	1959	22.5
Zhu, 1999[16]	1998	Shanghai-urban	5926	45.9
Zhu, 2000[17]	1987-1997	Shanghai-urban	1 243 337	29.4
Lin, 2000[18] [a]	1999	Guangdong-urban [b]	1052	47.7
Wu, 2000[19] [a]	1997	Shantou-mixed	951	29.9
Zhu, 2001[20]	2000	Shanghai-urban	7544	47.4
Liu, 2002[25]	1990-1999	Shangdong-mixed	28 294 [c]	45.3
Feng, 2002[21] [a]	2000	Hubei-urban [d]	1703	63.2
Lei, 2003[22]	1997-98	Guangdong-rural	20 891	25.9
Liu, 2003[23] [a]	1997-2001	Anhui-urban [e]	5352	47.8
Cheng, 2003[24]	1998-2001	Beijing-Shanghai-Chengdu urban	14 071	45.6

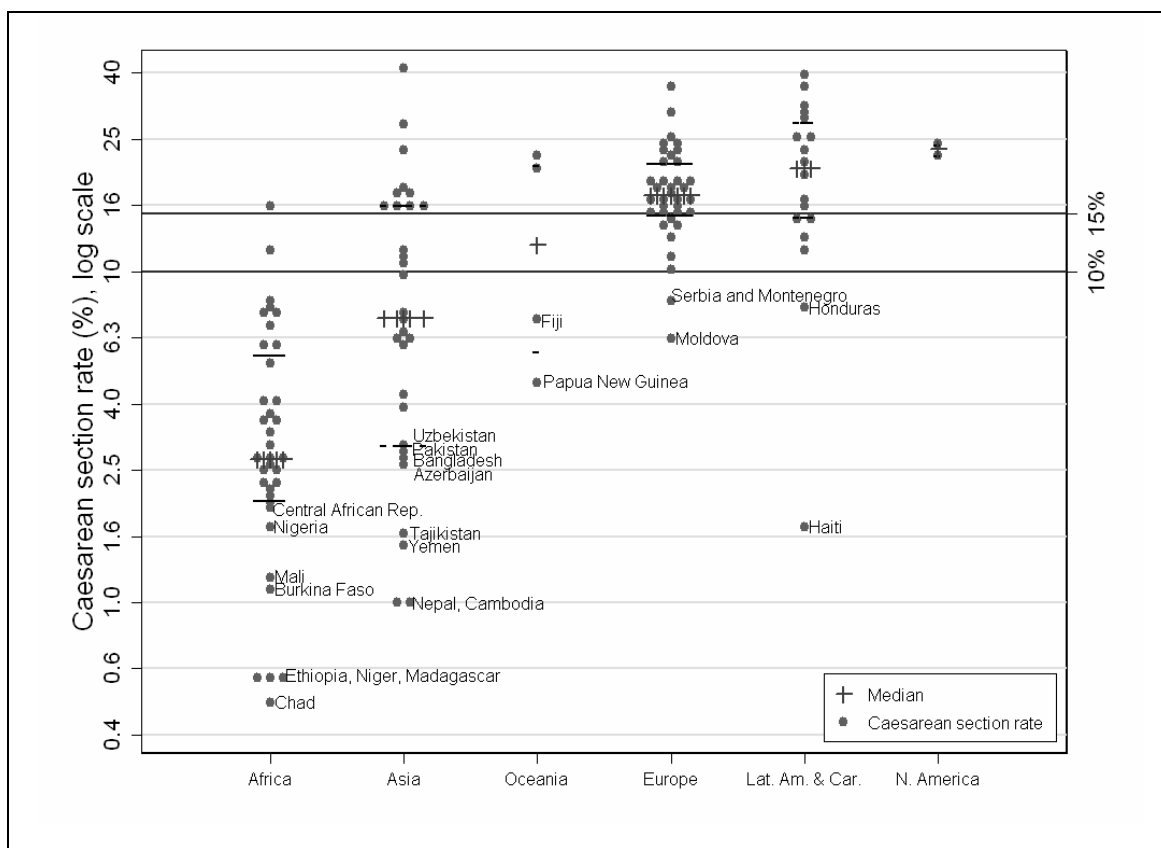[a] Contains data for several years; table shows latest year.
[b] Guangdong provincial hospital.
[c] Estimated from information on aggregate sample size for the period 1970-1999.
[d] Hubei province (Tongji Hospital).
[e] Anhui provincial hospital.

Figure 1: Dotplots of caesarean section rate by region, showing median and interquartile range; log scale (upper) and natural units (lower). Selected regional outliers identified with text labels.

Caesarean section rate (%)

- + Median
- • Caesarean section rate

China (mean of available observations)
Mexico
Italy
Brazil
Dominican Republic
Chile
Portugal
Cuba
China, Hong Kong SAR
Malta
Hungary
Venezuela, Colombia
Switzerland
USA
Lebanon
Germany
Uruguay
Ireland
Canada
Australia
New Zealand
Israel, Thailand
Turkey
South Africa
Bolivia, Nicaragua
Croatia
Netherlands
Peru
Saudi Arabia
Ukraine
Egypt
Kuwait
Romania
Guatemala
Kazakhstan
The Former Yugoslav Rep. of Macedonia
Viet Nam

15%
10%

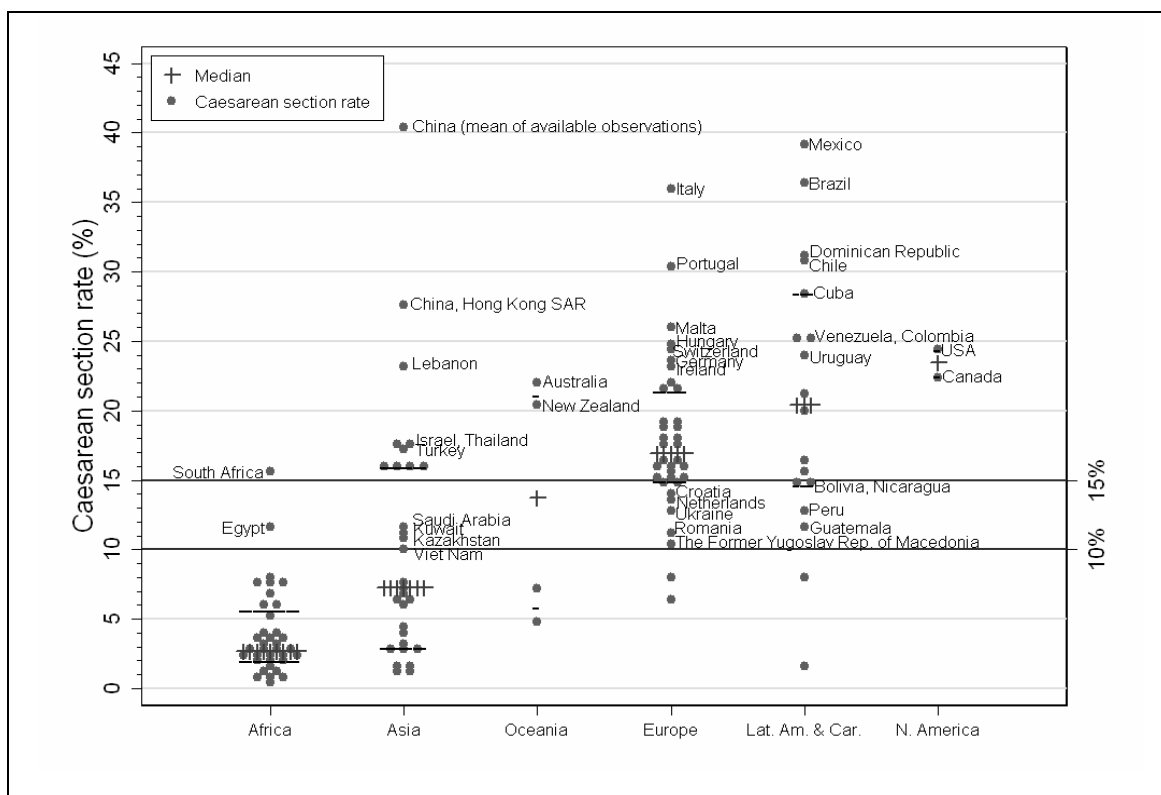Africa   Asia   Oceania   Europe   Lat. Am. & Car.   N. America

Figure 2: Caesarean section rates versus maternal mortality ratio (mmr), with selected countries identified; log-log plots showing smoothed local regression lines.
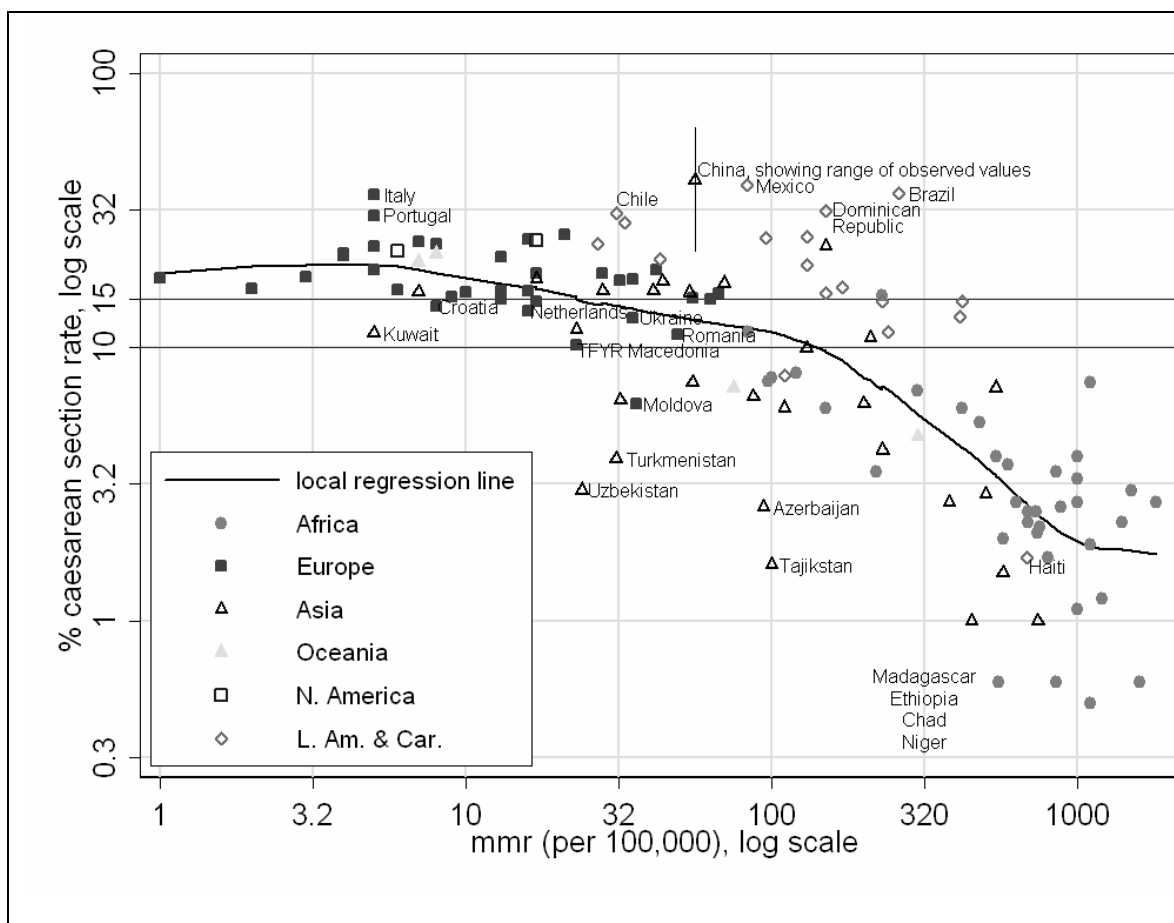
Figure 3: Caesarean section rate versus maternal mortality rate in countries with caesarean section rates above 15%, log-log plots.
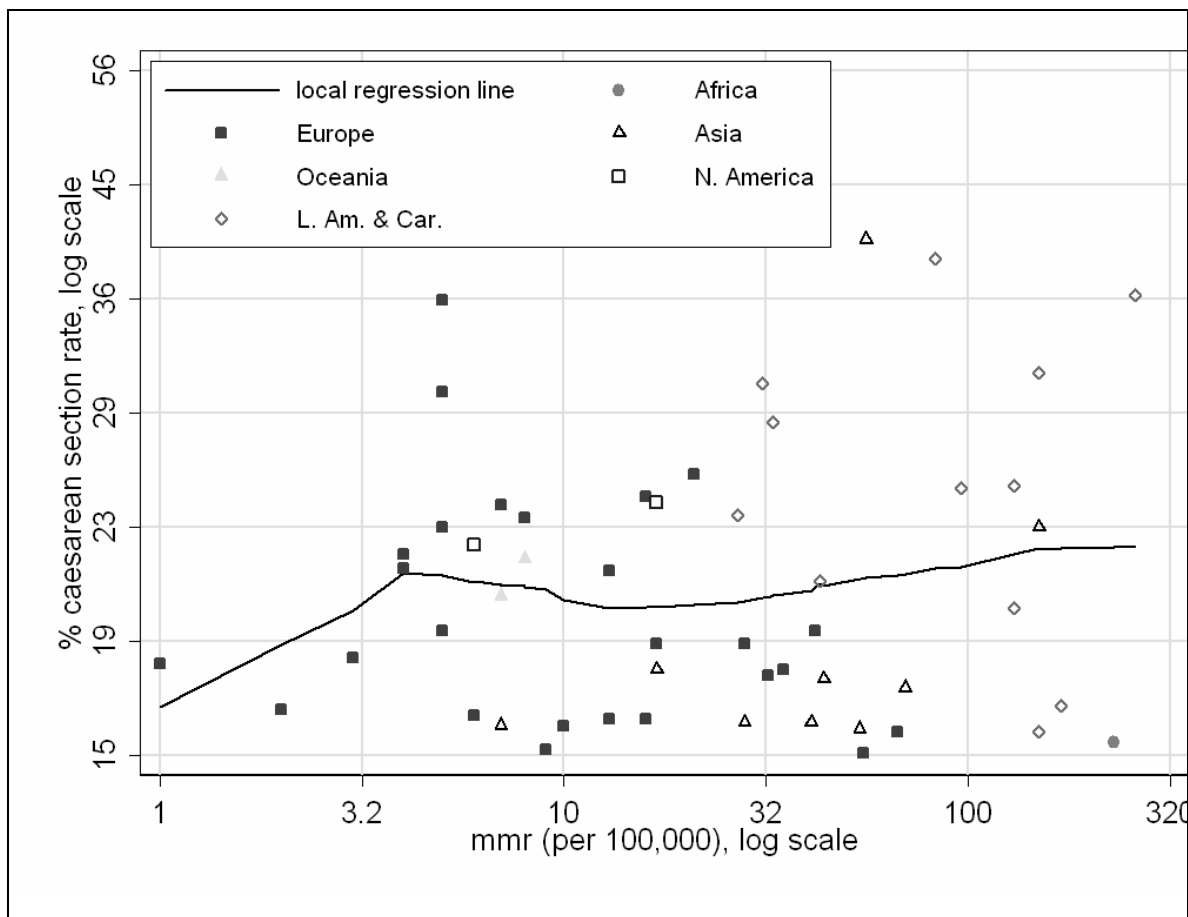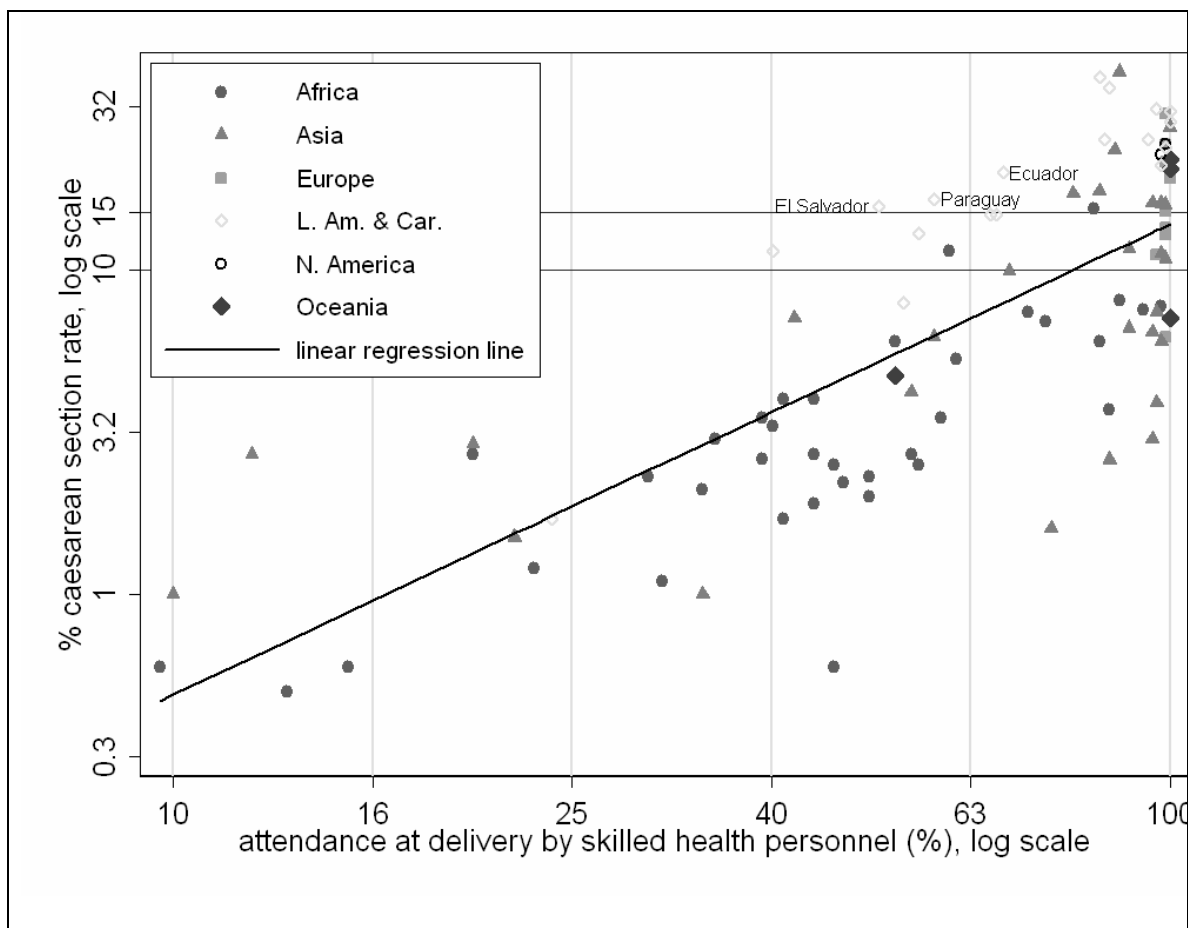
Figure 4: Caesarean section rate versus skilled birth attendant rate, log-log plot.

References

1. World Health Organization. Appropriate technology for birth. *Lancet* 1985;**2**:436-437.

2. Editorial: What is the right number of caesarean sections? *Lancet* 1997;**349**:815-816.

3. Peskin EG, Reine GM. A guest editorial: What is the correct caesarean rate and how do we get there? *Obstetrical & Gynecological Survey* 2002;**57**:189-190.

4. Wagner M. Choosing caesarean section. *Lancet* 2000;**356**:1677-1680.

5. Thomas J, Paranjothy S. Royal College of Obstetricians and Gynaecologists Clinical Effectiveness Support Unit. The National Sentinel Caesarean Section Audit Report. London, United Kingdom: RCOG Press, 2001.

6. National Collaborating Centre for Women's and Children's Health. *Caesarean Section: Clinical Guideline*. London, United Kingdom: RCOG Press, 2004.

7. Weil O, Fernandez H. Is safe motherhood an orphan initiative? *Lancet* 1999;**354**:940-943.

8. Murray CJL, Shengelia B, Gupta N, Moussavi S, Tandon A, Thieren M. Validity of reported vaccination coverage in 45 countries. *Lancet* 2003;**362**:1022-1027.

9. World Population Prospects. The 2002 revision. New York: United Nations, 2001.

10. Maternal mortality in 2000: Estimates developed by WHO, UNICEF and UNFPA. Geneva, Switzerland: World Health Organization, 2004.

11. World Health Organization. WHO Statistical Information System (WHOSIS). http://www3.who.int/whosis/menu.cfm. 2005.

12. World Health Statistics 2005. Geneva, Switzerland: World Health Organization, 2005.

13. Reproductive Health and Research. http://www.who.int/reproductive-health/. 2004. World Health Organization.

14. Cleveland WS. Robust Locally Weighted Regression and Smoothing Scatterplots. *Journal of the American Statistical Association* 1979;**74**:829-836.

15. Cai WW, Marks JS, Chen CHC, Zhuang YY, Morris L, Harris JR. Increased cesarean section rates and emerging patterns of health insurance in Shanghai. *American Journal of Public Health* 1998;**88**:777-780.

16. Zhu L, Zhou B, Hua J. Study on the situation of cesarean section in Shanghai. *Shanghai Medical Journal* 1999;**22**:349-351.

17. Zhu L, Zhou B, Qin M. Analysis on maternal deaths of cesarean section in Shanghai. *Zhonghua Fu Chan Ke Za Zhi* 2000;**35**:153-156.

18. Lin Y, Wen A, Zhang X. Analysis on the 10-year changes of rates and indications of cesarean section. *Guangdong Medical Journal* 2000;**21**:477-478.

19. Wu WL. Cesarean delivery in Shantou, China: a retrospective analysis of 1922 women. *Birth* 2000;**27**:86-90.

20. Zhu L, Qin M, Shi D. Study on the situation of cesarean section in Shanghai and the effect on maternal and infants' health. *China Maternal and Child Health* 2001;**16**:763-764.

21. Feng L, Yue Y. Analysis on the 45-year cesarean rate and its social factors. *Medicine and Society* 2002;**15**:14-16.

22. Lei H, Wen SW, Walker M. Determinants of caesarean delivery among women hospitalized for childbirth in a remote population in China. *Journal of Obstetrics and Gynaecology Canada* 2003;**25**:937-943.

23. Liu L, Feng X, Yi G. Relationship between cesarean section rate and changes of cesarean section and perinatal mortality. *Chinese Journal of Practical Gynecology and Obstetrics* 2003;**39**:43-44.

24. Cheng YM, Yuan W, Cai WD, Zhang WM, Wang TY, Wang Y *et al*. Study on the occurrence of cesarean section (CS) and factors related to CS in China. *Chinese Journal of Epidemiology* 2003;**24**:893-896.

25. Liu S, Yao L, Chen Z, Liu Z, Sun M. Study on the trend of changes in fetal macrosomia in Yantai during the past 30 years. *Chinese Journal of Obstetrics & Gynecology* 2002;**37**:469-471.

26. Wagner M. Fish can't see water: the need to humanize birth. *International Journal of Gynecology and Obstetrics* 2001;**75 Suppl 1**:S25-S37.

27. Dobson R. Caesarean section rate in England and Wales hits 21%. *BMJ* 2001;**323**:951.

28. Hamilton BE, Martin JA, Sutton PD. Births: Preliminary data for 2003. *National Vital Statistical Reports* 2004;**53**:1-18.

29. Hall MH, Bewley S. Maternal mortality and mode of delivery. *Lancet* 1999;**354**:776.

30. Bailey PE, Paxton A. Program note. Using UN process indicators to assess needs in emergency obstetric services. *International Journal of Gynecology and Obstetrics* 2002;**76**:299-305.

31. Tomeo CA, Rich-Edwards JW, Michels KB, Berkey CS, Hunter DJ, Frazier AL *et al*. Reproducibility and validity of maternal recall of pregnancy-related events. *Epidemiology* 1999;**10**:774-7.

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Summary

Rates of caesarean section are an issue of international public health concern in developed and developing countries. We set out to estimate the proportion of births by caesarean section (CS) at national level and worldwide, describe regional and subregional patterns and correlate these rates with other reproductive health indicators. We analysed nationally representative data available from surveys or vital registration systems on the proportion of births by CS. We used local non-parametric regression techniques to correlate CS with maternal mortality ratio, infant and neonatal mortality rates, and the proportion of births attended by skilled health personnel. Although unevenly distributed throughout the world, 15% of births worldwide occur by CS. Latin America and the Caribbean shows the highest rate (29.2%), and Africa shows the lowest (3.5%). In developed countries, the proportion of caesarean births is 21.1% whereas in least developed countries only 2% of deliveries are by CS. The analysis suggests the existence of a strong inverse relationship between caesarean section rates and maternal, infant and neonatal mortality in countries with high mortality levels. There is some suggestion of a direct relationship at lower levels of mortality. CS levels may respond primarily to economic determinants.

Introduction

In 1985 the World Health Organization stated: "There is no justification for any region to have caesarean section (CS) rates higher than 10–15%".[1] Two decades later, however, the optimal rate of births by CS remains controversial in both developing and developed countries.[2-4] In many developed countries, CS rates have increased, and attention has focused on strategies to reduce use due to concern that higher CS rates do not confer additional health gain but may increase maternal risks, have implications for future pregnancies and have resource implications for health services.[5;6] In developing countries, on the other hand, lack of availability of or access to maternal health services and the corresponding underuse of CS are part of a web of factors predisposing to high maternal and perinatal mortality.[7]

We set out to compile available CS rates by country and to calculate national, regional and global estimates of the proportion of caesarean deliveries so as to establish an epidemiological basis for global and regional needs assessment and further public health research and action. We correlate CS rates with maternal, infant and neonatal mortality, and with the proportion of births attended by skilled health personnel.

Methods

The CS rate is defined as the number of caesarean deliveries over the total number of live births, and is usually expressed as a percentage. CS rates were obtained from nationally representative surveys and from vital registration reports or from health authorities.

For developing countries, 53 identified surveys were undertaken by the Demographic and Health Surveys (DHS) programme, which represents the largest worldwide effort to obtain demographic and health data from nationally representative household surveys in developing countries (www.measuredhs.com). As the DHS use standardized questionnaires and methods of training, data collection and data processing, they are often considered the "best available gold standard" for many types of health indicator in developing countries.[8] DHS figures on CS rates refer to children born in the three years previous to the survey exercise. Data were collected through interviews in which mothers are asked: "was (name) delivered normally or by caesarean?" For countries with more than one available DHS survey, the most recent was used.

For developed countries, estimates based on published vital statistics from the most recent year available were used. For 34 European countries, data were obtained from the European Health for All Database (www.who.dk), maintained by the WHO European Regional Office, which includes basic demographic, socio-economic and health-related indicators. Health for All data are derived from routine national registration activities.

For 39 countries, mainly in the developing world, for which one of the above-mentioned sources was not available, a search was made of electronic publication databases, web search engines and government web sites. For example, the health

services of United States, Canada, Australia and New Zealand issue regular

publications and maintain web pages with up-to-date information on maternal health

indicators. If such efforts failed, however, an attempt was made to contact the

relevant health authorities (for example, in Thailand, Papua New Guinea, Botswana,

Cuba and Fiji). As population-representative data for China could not be obtained, we

reviewed available published information on subnational CS rates and calculated the

average. The Annex presents a comprehensive list of countries for which data were

identified as of March 2005, and for each country, the proportion of caesarean

deliveries, the data source and the year to which the data refer.

For regional and subregional averages, countries were grouped according to the

United Nations' classification.[9] Estimates were calculated as weighted means, with

weights the country's share of live births in the region. Regional and subregional

coverage was calculated as the proportion of total regional and subregional live births

which nationally representative data on CS were available. As discussed below, data for

China (representing approximately 15% of global live births in 2002) are not nationally

representative but were included in coverage calculations where noted.

We correlated CS rates with maternal mortality ratios (maternal deaths per 100

000 live births),[10] infant mortality rates (infant deaths per 1000 live births),[11] neonatal

mortality rates (neonatal deaths per 1000 live births),[12] and rates of skilled birth attendant

(%)[13] by transforming the variables to log scale and applying local non-parametric

regression techniques (lowess plots) to identify patterns in the data without assuming a particular functional form.

Regional and subregional estimates were calculated with Microsoft Excel 2003. Other statistical analyses were done and graphs were prepared using Stata 8.2.

Results

Coverage of estimates

Data were available for 126 countries, representing nearly 89% (74% excluding China) of global live births in 2002 (Table 1). At regional level, coverage ranged from 83% in Africa to 100% in Northern America. Coverage at subregional level was high except for Middle Africa, where estimates represent only 26% of live births in 2002 (data not obtained for Angola, Congo, Democratic Republic of the Congo and Equatorial Guinea).

Rates of CS worldwide

The global rate of CS is estimated here as 15% (Table 1). Rates are higher in developed countries and in Latin America and the Caribbean, but lower in other developing countries. The average rate of CS deliveries is 3.5% in Africa, with highest rates in South Africa (15.4%), Egypt (11.4%) and Tunisia (8%). Chad (0.4%), Madagascar, Niger and Ethiopia (0.6%) show the lowest CS rates in the world. Central African Republic, Burkina Faso, Mali and Nigeria all show CS rates below 2%.

The average CS rate in Asia is 15.9%. China, Hong Kong and Lebanon present the highest CS rates in Asia, with estimates of 40.5%, 27.4% and 23.3%, respectively. Nepal and Cambodia's rates are lowest (1%), followed by Yemen (1.5%). In Europe, the average rate of CS deliveries is 19%, with highest rates in Italy (36%) and Portugal (30.2%), and lowest rates in Serbia and Montenegro (8%) and Moldova (6.2%). The region Latin America and the Caribbean shows an average CS rate of 29.2%, with national rates ranging from 1.7% in Haiti and 7.9% in Honduras to 39.1%, 36.7%, 31.3% and 30.7% in Mexico, Brazil, the Dominican Republic and Chile, respectively.

In more developed regions (including Europe, Northern America, Japan, Australia and New Zealand) rates range between 6.2% and 36%, with an average of 21.1%. In less developed regions (Africa, Asia excluding Japan, Central and South America, and Oceania excluding Australia and New Zealand), variation is marked, ranging from 29.2% in Latin America and the Caribbean to 3.5% in Africa; the average rate is 14.3%. In least developed countries (49 countries mostly in Africa), CS rates range from 0.4% in Chad to 6% in Cape Verde, with an average rate of 2%.

Figure 1 shows dotplots, with median and interquartile range, of national CS rates by region, in both log (upper panel) and natural scale (lower panel). Displaying CS rates in log scale highlights countries with low rates (outliers), identified with text labels. The entire interquartile range of African countries is below the recommended range whereas in Europe, Northern America and Latin America and the Caribbean

nearly the entire interquartile range is above the recommended maximum. The same

data plotted in natural scale highlight countries with high rates (outliers), likewise

identified with text labels.

CS rates and other reproductive health indicators

Figure 2 (top panel) shows on log-log scale a plot of CS rates versus maternal

mortality, with selected countries identified. There is a clear inverse relation between

maternal mortality and CS rates over nearly the whole range of observed mortality,

although the strength of the relation weakens with decreasing maternal mortality ratio.

Smoothed local regressions of the logged variables indicate four piece-wise linear

segments of differing slope, with the segment at lowest maternal mortality (with a

positive slope) showing a direct, rather than inverse, relationship at very low levels of

mortality. The finding of progressively increasing slope from highest to lowest levels of

mortality (from more to less negative, with a positive slope at lowest mortality rates) is

robust to changes in local regression bandwidth from 0.35 to 0.70 (results not shown),

and, in most respects, to choice of mortality indicator (infant mortality, middle panel;

neonatal mortality, bottom panel), suggesting that it is a fundamental feature of the

observed data.

Nationally representative data were not obtained for China. However, a review of

recent studies yielded 11 reports of CS rates from different areas (Table 2).[14-24] Nowhere

were observed rates below 22.5%, and in one site the reported rate was 63.2%. The

unweighted mean of this convenience sample is 40.5%, and is virtually unchanged

ignoring extreme values (22.5%, 63.2%). In Figure 2, the vertical bar through data markers displaying the unweighted mean for China shows the full range of variation reported in Table 2. If additional observations from the studies listed in Table 2 are considered, evidence supporting a high national CS rate in China becomes stronger: over the past 25 years, sampled sites have witnessed exponential growth in CS rates, and a simple linear trend of the logged rate predicts a value of 56.3% for 2001 (Figure 3), suggesting that the mean of recent observations may well be a conservative estimate for the sample.[14] In sum, only the lowest of recent Chinese observations are close to the average CS rates found in countries with similar levels of mortality (Figure 2). At any rate, exclusion of Chinese data from the regressions depicted in Figure 2, as well as those reported subsequently, does not change the observed patterns in any respect.

Figure 2 (all panels) shows strong regional clustering suggesting common regional factors determine both CS and mortality rates. In Africa, almost all countries have low CS and high mortality rates. European countries span both sides of the local regression line for the low-mortality section. Australia and New Zealand and United States and Canada (Northern America) follow the European pattern. Countries in Latin America, with few exceptions, show CS rates above 15%, and even those with lower maternal mortality (e.g. Mexico, Chile) show notably high CS rates compared with countries in the same mortality range from other regions. Asian countries show the least regional clustering. Notable Asian outliers are the Central Asian republics (e.g. Tajikistan, Uzbekistan, Turkmenistan and Azerbaijan), with very low CS rates, and China, with an apparently very high rate.

Figure 4 displays results from local regressions restricted to countries with CS rates above or below 15%. Although below 15% higher CS rates are unambiguously correlated with lower maternal mortality (lower panel), above this range, higher CS rates are only predominantly correlated with higher maternal mortality (upper panel). A similar pattern is found for infant and neonatal mortality (results not shown). The stratified analysis therefore supports the evidence presented in Figure 2 that, above a certain ceiling, higher CS rates may be associated with poorer outcomes.

CS rates are highly correlated with the proportion of births attended by trained health personnel (Figure 5). With the exception of countries in Latin America, countries with skilled birth attendant rates below 80% consistently show CS rates well below the recommended range of 10−15%. Latin America is therefore unique in containing several countries (in particular, El Salvador, Paraguay and Ecuador) that appear to offer dramatically differing levels of obstetric care to their populations.

Discussion

Since publication of the WHO consensus statement in 1985, debate regarding desirable levels of CS has continued;[2-4] nevertheless, this paper represents the first attempt to provide a global and regional comparative analysis of national rates of caesarean delivery and their correlation with other indicators of reproductive health. With the exception of Latin American and Caribbean countries, as well as a few countries in Asia, the majority of countries with high mortality rates have CS rates well below the

recommended range of 10–15%, and in these countries there appears to be a strong

ecologic association between increasing CS rates and decreasing mortality.

Interpretation of the relationship between CS rates and mortality in countries with

low mortality rates is more ambiguous; nevertheless, the sum total of the evidence

presented here supports the hypothesis that, as has been argued previously,[25] when CS

rates rise substantially above 15%, risks to reproductive health outcomes may begin to

outweigh benefits. To rebut a possible counterargument that this finding is a mere chance

disposition of the data, we analysed CS rates versus per-capita national income. Figure 6

shows that CS rates display a broadly similar correlation (albeit with opposite slope) with

income per head as with mortality rates. However, here the smoothed local regressions

yield three quasi-linear segments of different slope. Significantly, there is no fourth

downturning segment at the highest levels of income. Such an S-shaped ("sigmoid")

curve is typical of many classes of growth systems and suggests that CS rates in fact

respond primarily to economic determinants, initially increasing slowly at low income

and CS levels, then increasing more rapidly at intermediate income and CS levels and

finally increasing more slowly again as saturation levels of CS are gradually approached

at higher levels of income. Although income and mortality show an unambiguously

strong linear correlation in log scale (results not shown), even at very high levels of

income there is no suggestion of opposite sign in the plot of income versus CS rates, the

contrary of what would be expected if the downturning segments in Figure 2 were merely

a chance occurrence.

In many developed countries, CS rates have been steadily increasing over the last decade.[26;27] For example, preliminary data for 2003 in the United States suggest that the CS rate has risen for the seventh straight year, to 27.6%.[27] Given levels of utilization of surgical procedures unprecedented in the history of modern obstetric care, it is increasingly important to evaluate the corresponding experience with maternal and infant health outcomes. According to data from the United Kingdom Confidential Enquiry into Maternal Deaths, an elective CS with no emergency presents a 2.84 times greater chance of maternal death than a vaginal birth,[28] and thus, when population CS rates rise beyond medically necessary levels, risks may outweigh benefits. High CS rates may even be an indicator for excess maternal mortality in developed countries.[25] However, in order to conclusively evaluate the relationship between reproductive mortality and high CS rates, developed countries will need to reinforce their monitoring strategies and more detailed individual-level analyses will need to be performed.

On the other hand, in countries designated by the United Nations as least developed,[9] uniformly low CS rates and high levels of maternal, infant and neonatal mortality are observed. In these 49 countries (34 of which are in Africa), the average CS rate is only 2%, indicating a clear need to improve access to surgical obstetric care.

Outliers in Figures 1 and 2 suggest countries that may be facing unique problems relative to their regional counterparts. For example, in countries with relatively low mortality where CS rates remain substantially below the reference range (e.g. Azerbaijan, Tajikistan, Turkmenistan, Uzbekistan) policy makers may wish to investigate whether

systemic obstacles or bottlenecks impede delivery of the procedure when medically necessary. Conversely, policy makers in countries with relatively high mortality but where CS rates are sharply above the reference range (e.g. Brazil, Dominican Republic, Mexico) or where other reproductive health system indicators offer reasons for concern (e.g. El Salvador, Paraguay, Ecuador), may want to investigate whether their health systems are delivering medically appropriate obstetric care and to prioritize a monitoring strategy for CS rates and reproductive mortality.

The proportion of births by CS has been proposed as a proxy indicator for measuring access, availability or appropriateness of medical care, as well as for monitoring changes in maternal mortality in developing countries.[29] The strength of the correlation in the high mortality region of Figure 2 would, with the above-noted qualifications, support these claims. Moreover, while measuring progress towards the Millennium Development Goals (www.developmentgoals.org) for reproductive health lags, CS rates (especially in conjunction with other indicators) may provide a valuable proxy indicator. Information on CS is relatively easy to collect by surveys since mothers can be expected to remember more reliably the type of delivery than, for example, who attended the birth, the number of antenatal care visits, or the antenatal tests performed.[30] Moreover, where data are available, subnational differences (e.g. urban and rural) suggest health inequalities. For example, in Bangladesh, the proportion of deliveries by CS is 7.5% in urban areas but only 1.7% in rural areas.

Skilled birth attendant rates are conventionally used as a process indicator for maternal mortality, an interpretation that would seem to have greater validity for less and least developed countries, since, when rates of skilled birth attendant are high, they are no longer a sensitive indicator for the availability of surgical obstetric care (refer Figure 5). While both measures can serve as access indicators, each refers to a distinct level of services.

The limitations of ecological analysis must be kept in mind: the validity of inferences regarding a causal association between CS rates and reproductive health outcomes depends on the absence of uncontrolled factors and interactions, a condition which is almost surely not met here. Moreover, a number of large countries remain without national data on CS, especially in Western Asia (Iraq and Syria) and Middle Africa (Angola, Congo, Democratic Republic of the Congo). Although all available information supports the conclusion of high current rates of CS in China,[14] substantial uncertainty surrounds our provisional estimate of 40.5%, and would be substantially mitigated only by more data on rural rates of CS in that country (refer Table 2).

This global and regional overview of CS rates establishes a comparative basis for the investigation of country-specific determinants. It also provides a first step supporting an evidence-based needs assessment in surgical obstetric care and highlights a number of hypotheses that warrant more detailed research.

Conflict of interest (including financial interest)

None

Authors' contributions

APB, MM and JAL contributed equally. APB and MM conceived of the study, compiled

the data and participated in all the analyses. JAL designed and executed the exploratory

and statistical analyses. APB, MM and JAL drafted the manuscript. WB provided key

input and interpretations regarding China. APB, MM, JAL, WB, JT, PVL and MW

provided key interpretive and critical input and revised the manuscript. APB, MM and

JAL are guarantors.

Figures and tables

Table 1: Caesarean section rates by region and subregion and coverage of the estimates (figures in brackets represent coverage excluding data from China).

Region/subregion[a]	Births by caesarean section (%)	Range, minimum to maximum (%)	Coverage of estimates[b] (%)
World total	15.0	0.4-40.5	89 (74)[c]
More developed regions	21.1	6.2-36.0	90
Less developed countries	14.3	0.4-40.5	89 (72)[c]
Least developed countries	2.0	0.4-6.0	74
Africa	**3.5**	**0.4-15.4**	**83**
Eastern Africa	2.3	0.6-7.4	93
Middle Africa	1.8	0.4-6.0	26
Northern Africa	7.6	3.5-11.4	84
Southern Africa	14.5	6.9-15.4	93
Western Africa	1.9	0.6-6.0	95
Asia	**15.9**	**1.0-40.5**	**89 (65)[c]**
Eastern Asia	40.5	27.4-40.5	90 (0.31)[c]
South-Central Asia	5.8	1.0-10.8	93
South-Eastern Asia	6.8	1.0-17.4	83
Western Asia	11.7	1.5-23.3	75
Europe	**19.0**	**6.2-36.0**	**99**
Eastern Europe	15.2	6.2-24.7	100
Northern Europe	20.1	14.9-23.3	100
Southern Europe	24.0	8.0-36.0	97
Western Europe	20.2	13.5-24.3	100
Latin America & the Caribbean	**29.2**	**1.7-39.1**	**92**
Caribbean	18.1	1.7-31.3	78
Central America	31.0	7.9-39.1	98
South America	29.3	12.9-36.7	90
Northern America	**24.3**	**22.5-24.4**	**100**
Oceania	**14.9**	**4.7-21.9**	**92**
Australia/New Zealand	21.6	20.4-21.9	100
Melanesia	4.9	4.7-7.1	87
Micronesia	na[d]	na	0
Polynesia	na	na	0

[a] Countries categorized according to the UN classification. Countries with a population of less than 140 000 in 2000 are not included.

[b] Refers to the proportion of live births for which nationally representative data were available.

[c] Figures in brackets represent coverage excluding data from China.

[d] na = data not available.

Table 2: Caesarean section rates in China.

Source	Year	Place	Sample size	CS (%)
Cai, 1998[14] [a]	1993	Shanghai-urban	1959	22.5
Zhu, 1999[15]	1998	Shanghai-urban	5926	45.9
Zhu, 2000[16]	1987-1997	Shanghai-urban	1 243 337	29.4
Lin, 2000[17] [a]	1999	Guangdong-urban [b]	1052	47.7
Wu, 2000[18] [a]	1997	Shantou-mixed	951	29.9
Zhu, 2001[19]	2000	Shanghai-urban	7544	47.4
Liu, 2002[24]	1990-1999	Shangdong-mixed	28 294 [c]	45.3
Feng, 2002[20] [a]	2000	Hubei-urban [d]	1703	63.2
Lei, 2003[21]	1997-98	Guangdong-rural	20 891	25.9
Liu, 2003[22] [a]	1997-2001	Anhui-urban [e]	5352	47.8
Cheng, 2003[23]	1998-2001	Beijing-Shanghai-Chengdu urban	14 071	45.6

[a] Contains data for several years; table shows latest year.
[b] Guangdong provincial hospital.
[c] Estimated from information on aggregate sample size for the period 1970-1999.
[d] Hubei province (Tongji Hospital).
[e] Anhui provincial hospital.

Figure 1: Dotplots of caesarean section rate by region, showing median and interquartile range; log scale (upper) and natural units (lower). Selected regional outliers identified with text labels.
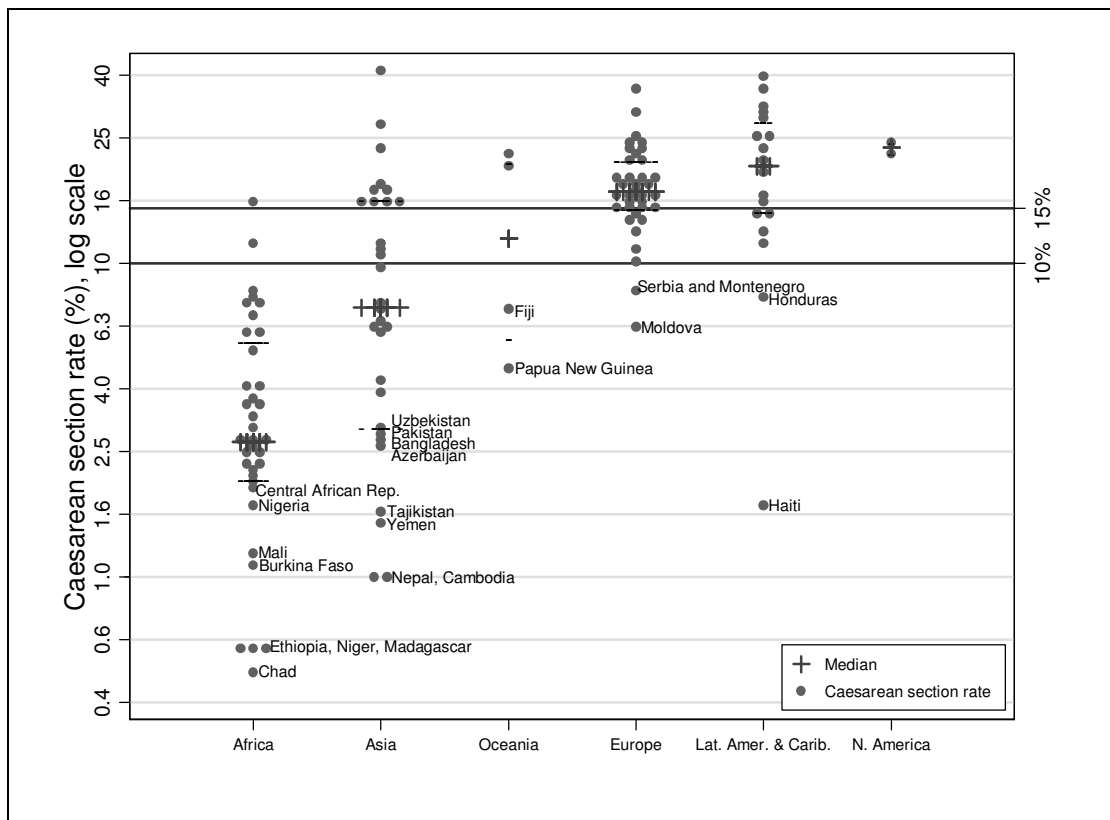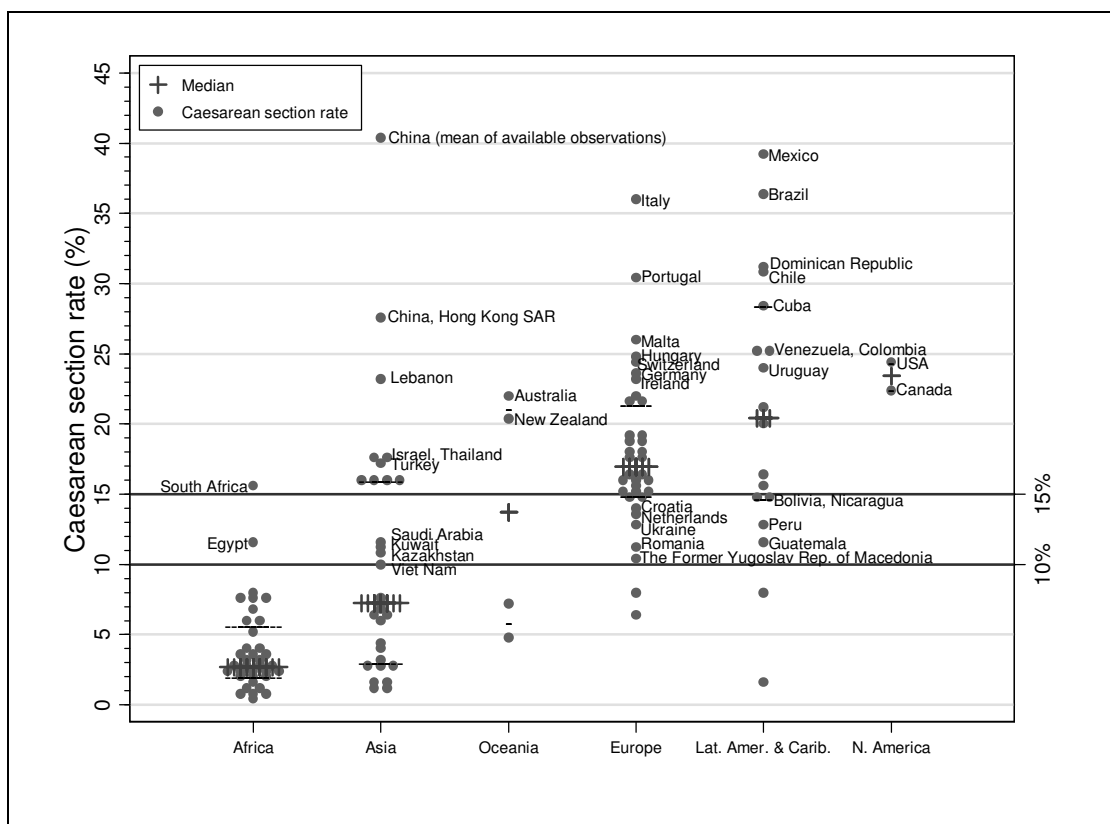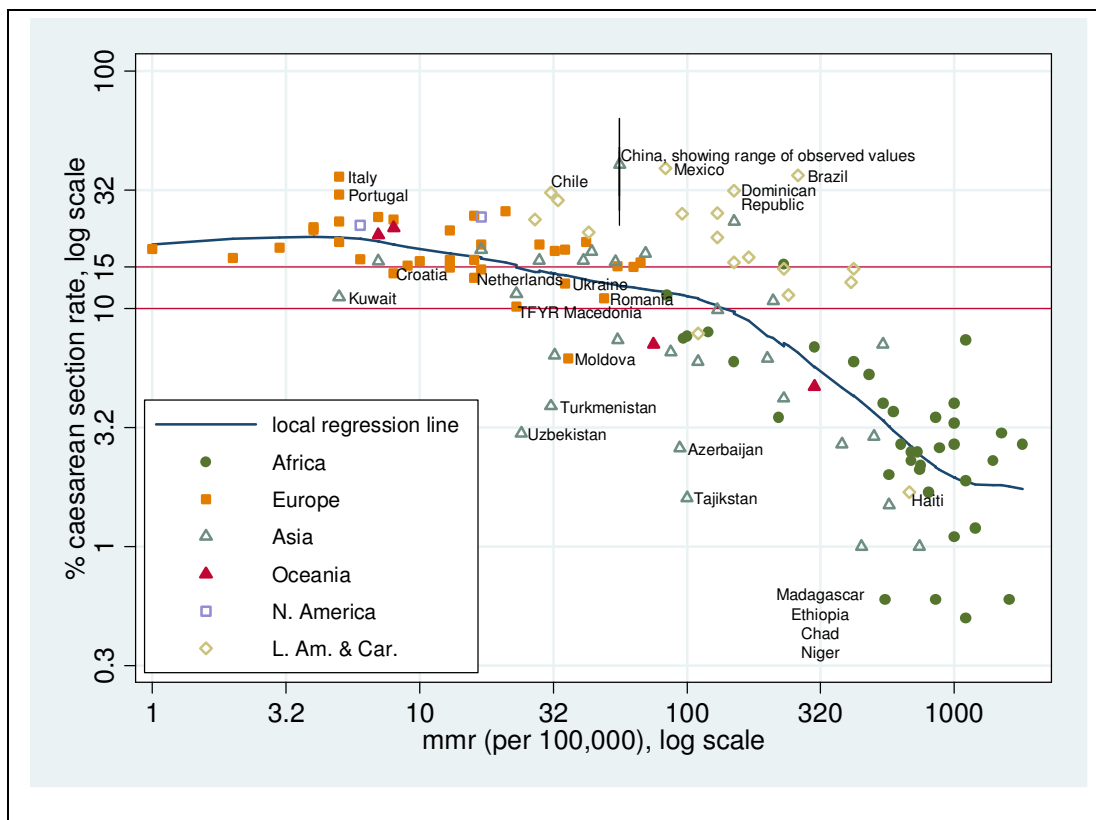
Figure 2: Caesarean section rates versus maternal mortality ratio (mmr, top panel), with selected countries identified, infant mortality (imr, middle panel) and neonatal mortality (nmr, bottom panel); log-log plots showing smoothed local regression lines.
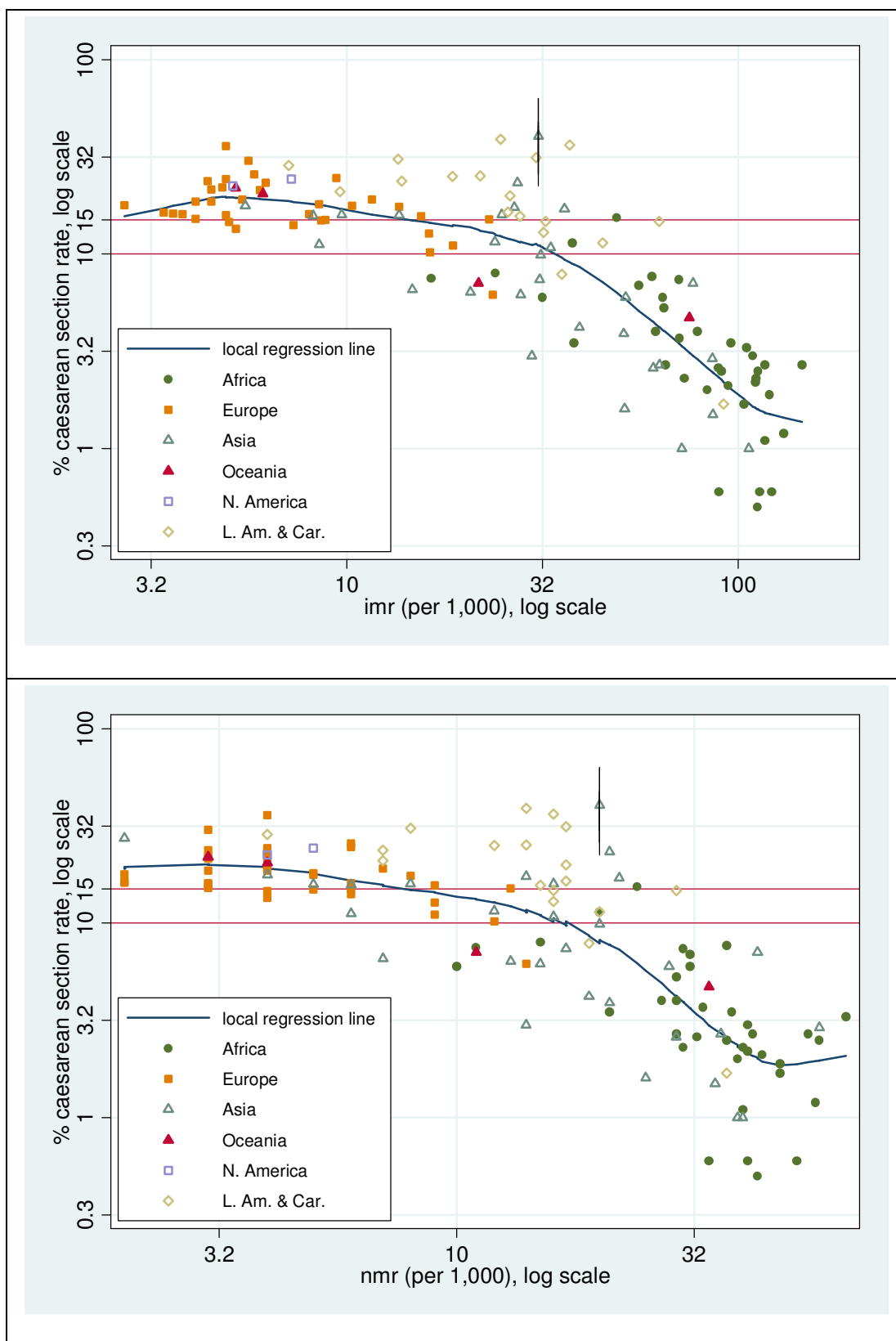
Figure 3: All available observations of caesarean section rates (log scale) in China, urban (u), rural (r) and mixed (m) populations, showing the linear trend; data markers indicate relative sample size.
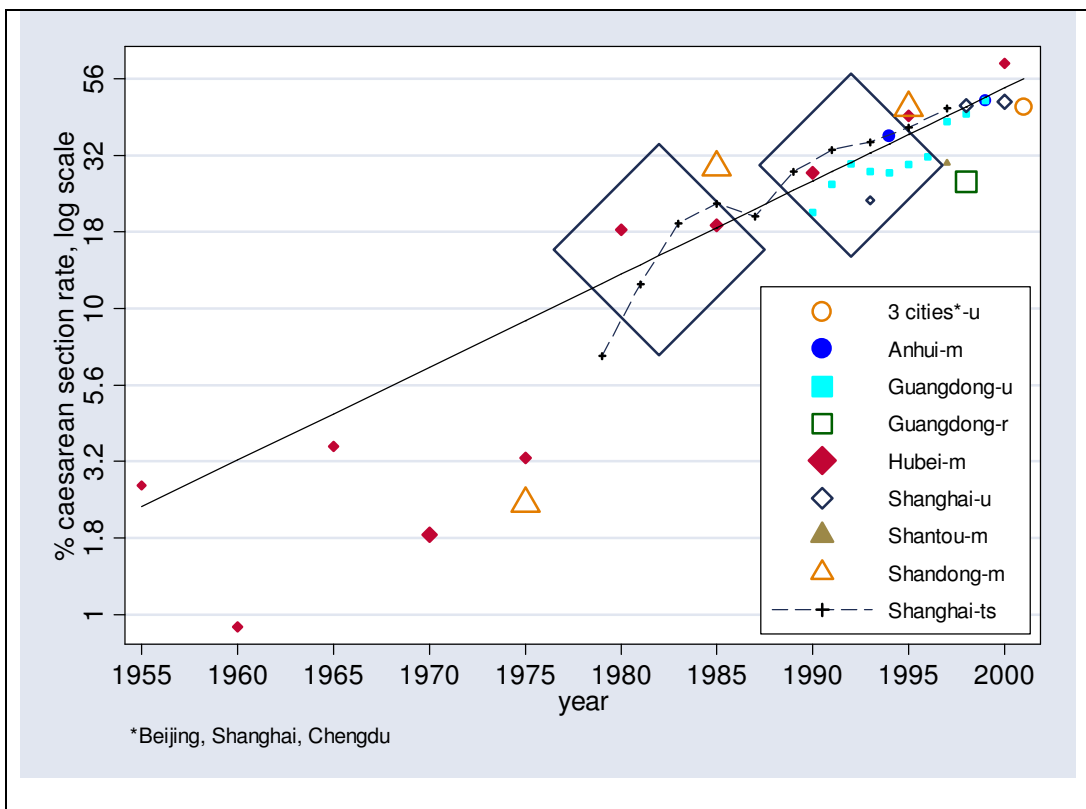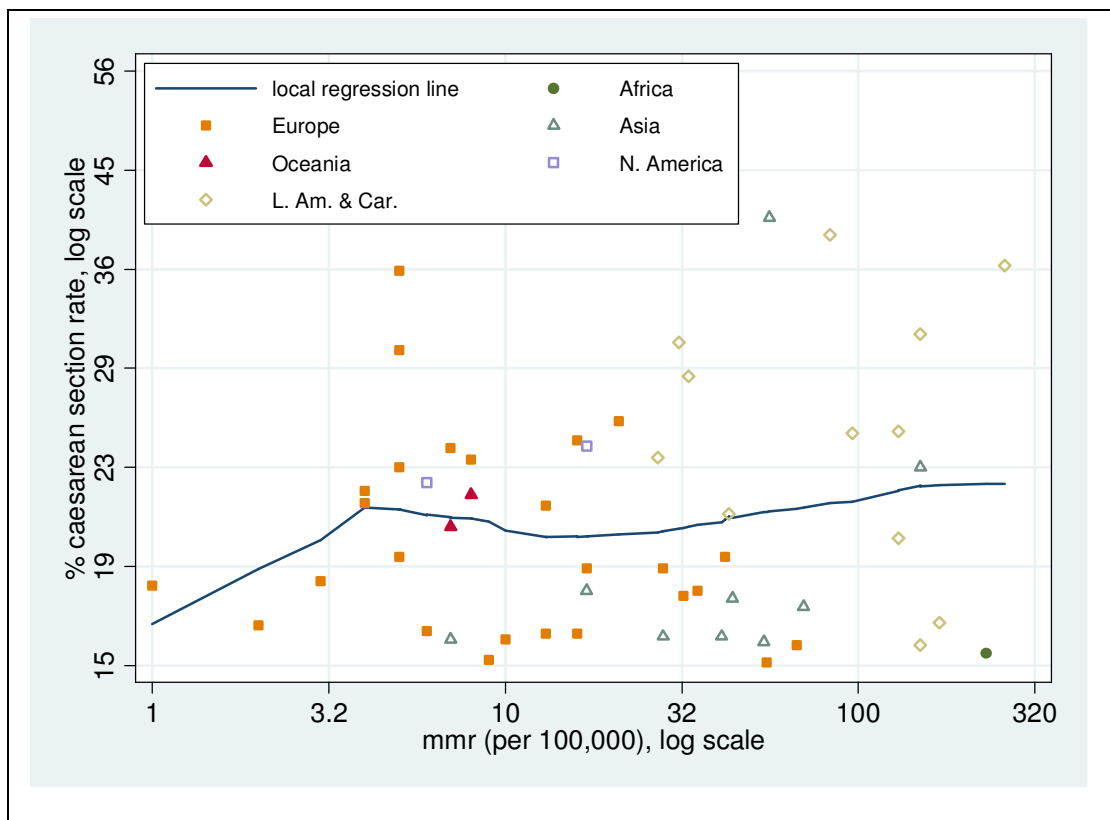
Figure 4: Caesarean section rate versus maternal mortality rate in countries with ceasarean section rates above 15% (upper panel) and below 15% (lower panel), log-log plots.
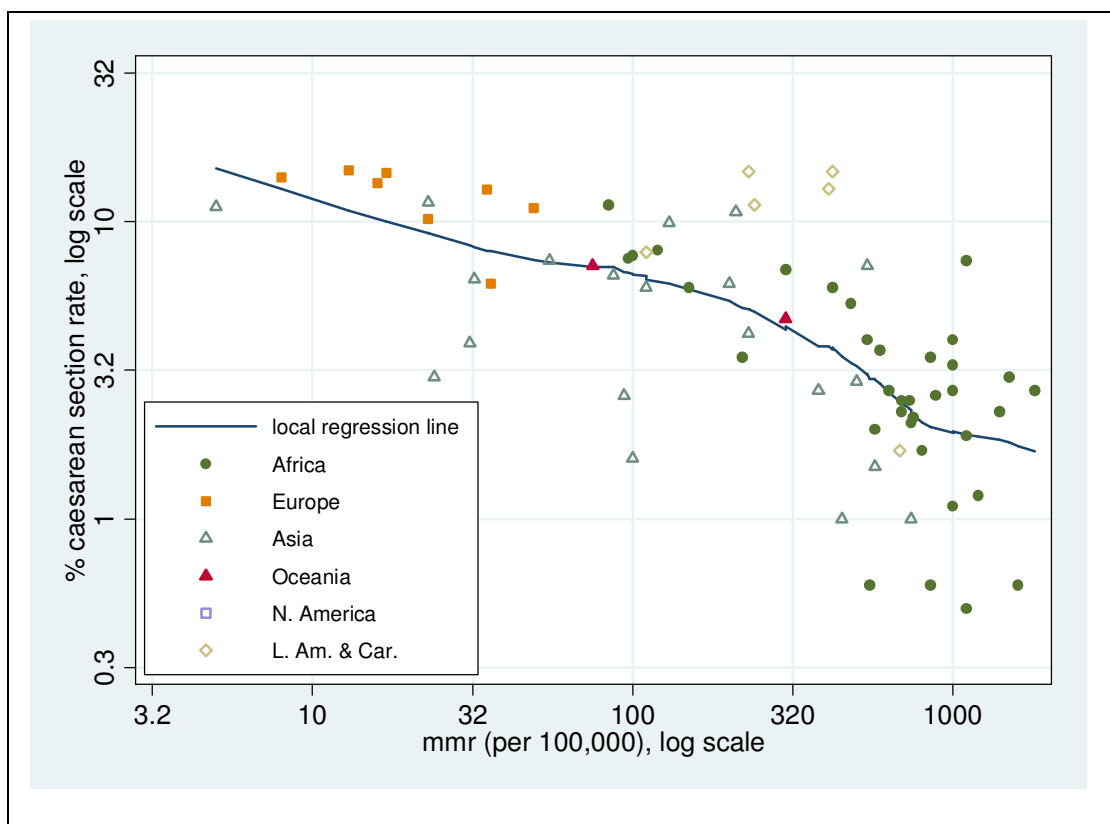
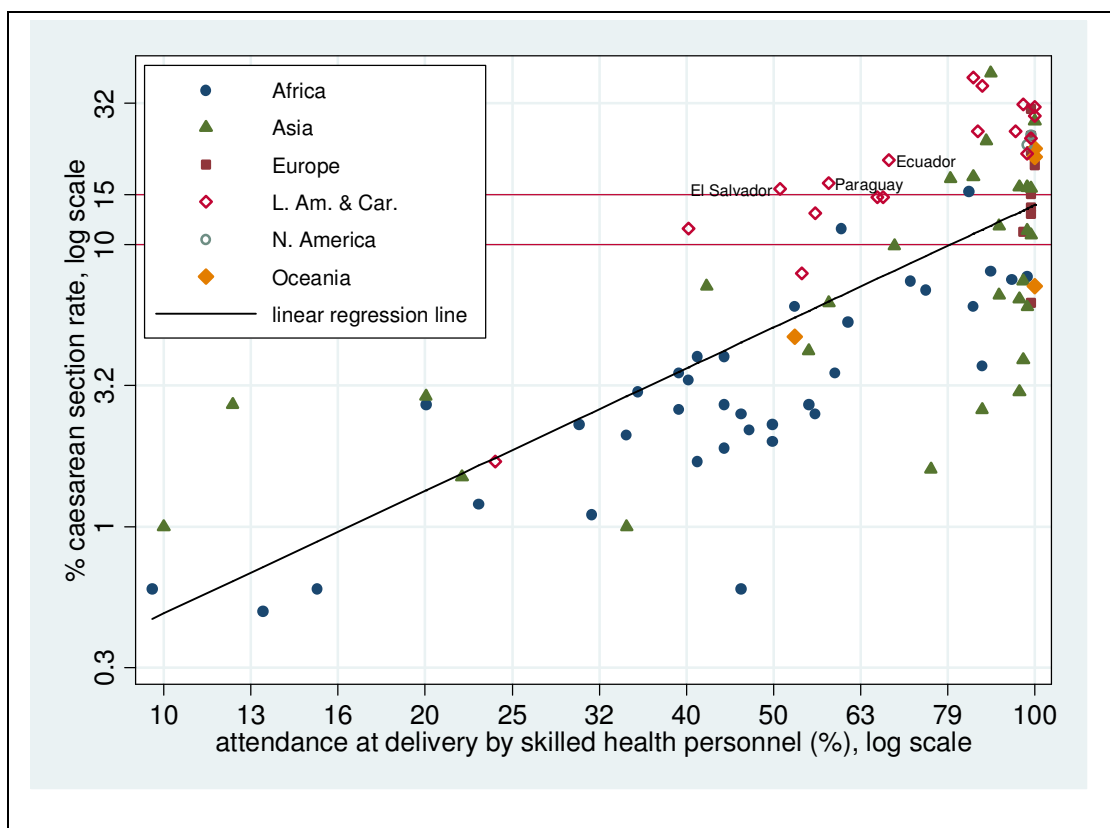**Figure 5: Caesarean section rate versus skilled birth attendant rate, log-log plot.**
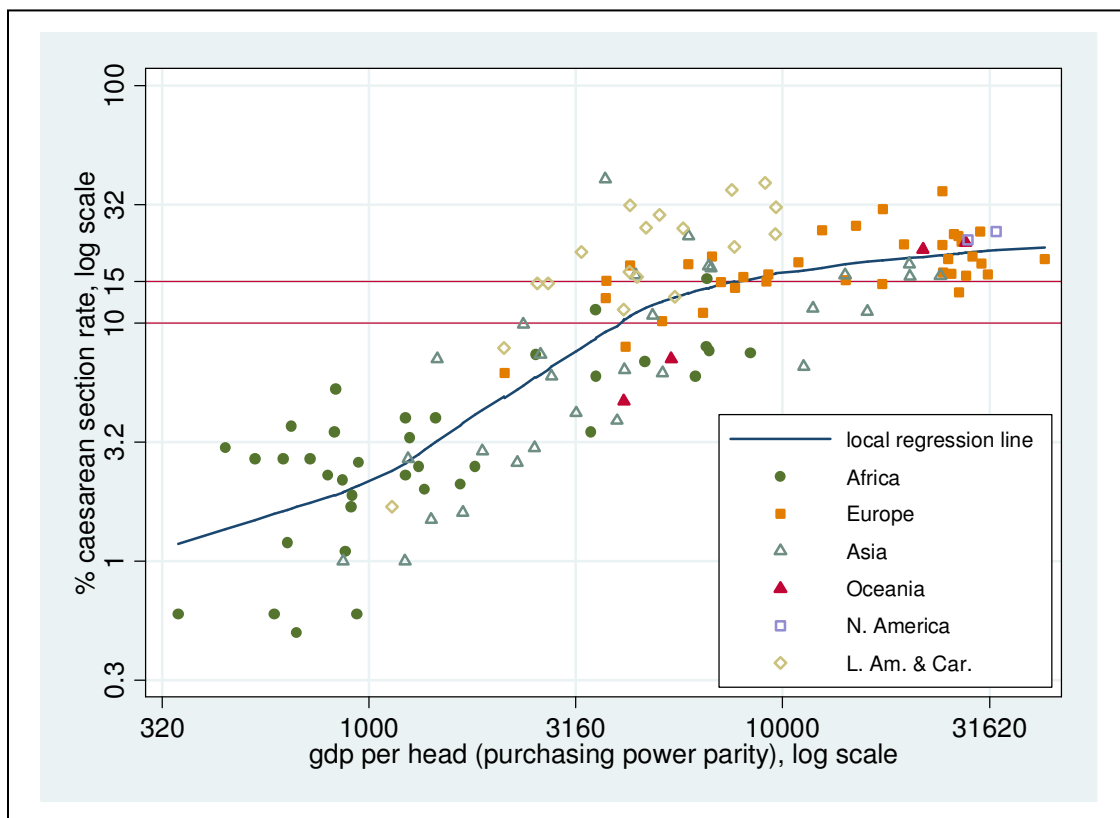
Figure 6: Caesarean section rates versus income per capita (I$), log-log plot.

References

1. World Health Organization. Appropriate technology for birth. *Lancet* 1985;**2**:436-7.

2. Editorial: What is the right number of caesarean sections? *Lancet* 1997;**349**:815-6.

3. Peskin EG, Reine GM. A guest editorial: What is the correct caesarean rate and how do we get there? *Obstetrical and Gynecological Survey* 2002;**57**:189-90.

4. Wagner M. Choosing caesarean section. *Lancet* 2000;**356**:1677-80.

5. Thomas J, Paranjothy S. Royal College of Obstetricians and Gynaecologists Clinical Effectiveness Support Unit. The National Sentinel Caesarean Section Audit Report. London, United Kingdom: RCOG Press, 2001.

6. National Collaborating Centre for Women's and Children's Health. *Caesarean Section: Clinical Guideline*. London, United Kingdom: RCOG Press, 2004.

7. Weil O, Fernandez H. Is safe motherhood an orphan initiative? *Lancet* 1999;**354**:940-3.

8. Murray CJL, Shengelia B, Gupta N, Moussavi S, Tandon A, Thieren M. Validity of reported vaccination coverage in 45 countries. *Lancet* 2003;**362**:1022-7.

9. World Population Prospects. The 2002 revision. New York: United Nations, 2001.

10. Maternal mortality in 2000: Estimates developed by WHO, UNICEF and UNFPA. Geneva, Switzerland: World Health Organization, 2004.

11. World Health Organization. WHO Statistical Information System (WHOSIS). http://www3.who.int/whosis/menu.cfm .

12. World Health Statistics 2005. Geneva, Switzerland: World Health Organization, 2005.

13. Reproductive Health and Research. http://www.who.int/reproductive-health/ . World Health Organization.

14. Cai WW, Marks JS, Chen CHC, Zhuang YY, Morris L, Harris JR. Increased cesarean section rates and emerging patterns of health insurance in Shanghai. *American Journal of Public Health* 1998;**88**:777-80.

15. Zhu L, Zhou B, Hua J. Study on the situation of cesarean section in Shanghai. *Shanghai Medical Journal* 1999;**22**:349-51.

16. Zhu L, Zhou B, Qin M. Analysis on maternal deaths of cesarean section in Shanghai. *Zhonghua Fu Chan Ke Za Zhi.* 2000;**35**:153-6.

17. Lin Y, Wen A, Zhang X. Analysis on the 10-year changes of rates and indications of cesarean section. *Guangdong Medical Journal* 2000;**21**:477-8.

18. Wu WL. Cesarean delivery in Shantou, China: a retrospective analysis of 1922 women. *Birth* 2000;**27**:86-90.

19. Zhu L, Qin M, Shi D. Study on the situation of cesarean section in Shanghai and the effect on maternal and infants' health. *China Maternal and Child Health* 2001;**16**:763-4.

20. Feng L, Yue Y. Analysis on the 45-year cesarean rate and its social factors. *Medicine and Society* 2002;**15**:14-6.

21. Lei H, Wen SW, Walker M. Determinants of caesarean delivery among women hospitalized for childbirth in a remote population in China. *Journal of Obstetrics and Gynaecology Canada* 2003;**25**:937-43.

22. Liu L, Feng X, Yi G. Relationship between cesarean section rate and changes of cesarean section and perinatal mortality. *Chinese Journal of Practical Gynecology and Obstetrics* 2003;**39**:43-4.

23. Cheng YM, Yuan W, Cai WD, Zhang WM, Wang TY, Wang Y *et al*. Study on the occurrence of cesarean section (CS) and factors related to CS in China. *Chinese Journal of Epidemiology* 2003;**24**:893-6.

24. Liu S, Yao L, Chen Z, Liu Z, Sun M. Study on the trend of changes in fetal macrosomia in Yantai during the past 30 years. *Chinese Journal of Obstetrics & Gynecology* 2002;**37**:469-71.

25. Wagner M. Fish can't see water: the need to humanize birth. *International Journal of Gynaecology and Obstetrics* 2001;**75 Suppl 1**:S25-S37.

26. Dobson R. Caesarean section rate in England and Wales hits 21%. *BMJ* 2001;**323**:951.

27. Hamilton BE, Martin JA, Sutton PD. Births: Preliminary data for 2003. *National Vital Statistical Reports* 2004;**53**:1-18.

28. Hall MH, Bewley S. Maternal mortality and mode of delivery. *Lancet* 1999;**354**:776.

29. Bailey PE, Paxton A. Program note. Using UN process indicators to assess needs in emergency obstetric services. *International Journal of Gynaecology and Obstetrics* 2002;**76**:299-305.

30. Tomeo CA, Rich-Edwards JW, Michels KB, Berkey CS, Hunter DJ, Frazier AL *et al*. Reproducibility and validity of maternal recall of pregnancy-related events. *Epidemiology* 1999;**10**:774-7.