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Abstract: This Lancet Series paper, one of three on the high rate of Caesarean Section (CS), describes the global, regional and selected country levels, trends, determinants and inequalities in CS. Based on data from 169 countries representing 98.4% of the world's births, we estimate that 21.1% (95% uncertainty range 19.9-22.4%) or 29.7 million births occurred through CS in 2015, representing almost a doubling since 2000 (12.1%; 10.9-13.3%). The differences in CS rates between regions in 2015 were tenfold, with a high of 44.3% (41.3-47.4%) in the Latin America and the Caribbean region and a low of 4.1% (3.6-4.6%) in the West and Central African region. The global and regional increases were driven both by increasing coverage of births by health facilities (66.5% of the global increase) and higher CS rates within health facilities (33.5%), with considerable variation between regions. Based on the most recent data, population-based CS rates exceeded 15% of births in 63% of 169 countries, while 28% countries had CS rates below 10%. National CS rates varied from 0.6% in South Sudan to 58.1% in the Dominican Republic. Within-country disparities in CS rates were also very large, with a six-fold difference in CS rates between births in the richest and poorest quintiles in low- and middle-income countries, markedly high CS rates among low obstetric risk births among especially more educated women in Brazil and China and 1.6 times higher CS rates in private facilities compared to public facilities.

The global epidemiology of Caesarean Sections: major increases and wide disparities

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Key messages

- Global CS rates are high and increasing. In 2015, an estimated 21.1% or 29.7 million births occurred through CS, which represented almost a doubling since 2000. The differences in population CS rates between regions were very large, with a high of 44.3% in the Latin America and the Caribbean region and a low of 4.1% in West and Central African region.

- There are large persistent disparities in the CS rate between and within countries. Population CS rates are increasing in all regions but are still well below 10% in sub-Saharan Africa. Many poor women in low- and middle-income countries still do not have adequate access to CS. In several countries, poor women have CS rates close to 0%, implying that women and babies die because they cannot access life-saving surgery during labour.

- At the other end, there is strong evidence of massive over-use of CS in many countries. CS rates are still increasing in most regions with rates well over 15% by 2015, driven by extremely high CS rates among wealthier women, high rates in private facilities and by high proportions of women at low risk of obstetric complications giving birth by CS.

Abstract

This Lancet Series paper, one of three on the high rate of Caesarean Section (CS), describes the global, regional and selected country levels, trends, determinants and inequalities in CS. Based on data from 169 countries representing 98.4% of the world's births, we estimate that 21.1% (95% uncertainty range 19.9-22.4%) or 29.7 million births occurred through CS in 2015, representing almost a doubling since 2000 (12.1%; 10.9-13.3%). The differences in CS rates between regions in 2015 were tenfold, with a high of 44.3% (41.3-47.4%) in the Latin America and the Caribbean region and a low of 4.1% (3.6-4.6%) in the West and Central African region. The global and regional increases were driven both by increasing coverage of births by health facilities (66.5% of the global increase) and higher CS rates within health facilities (33.5%), with considerable variation between regions.   Based on the most recent data, population-based CS rates exceeded 15% of births in 63% of 169 countries, while 28% countries had CS rates below 10%. National CS rates varied from 0.6% in South Sudan to 58.1% in the Dominican Republic. Within-country disparities in CS rates were also very large, with a six-fold difference in CS rates between births in the richest and poorest quintiles in low- and middle-income countries, markedly high CS rates among low obstetric risk births among especially more educated women in Brazil and China and 1.6 times higher CS rates in private facilities compared to public facilities.

Introduction

Caesarean section (CS) is a life-saving intervention for women and newborns when complications occur, such as antepartum haemorrhage, fetal distress, abnormal fetal presentation and hypertensive disease. CS is the most common major surgical intervention in many countries.[1] Rates of CS have been rising during the last three decades to levels well above recommended CS rates of 10-15%, driven by major increases in non-medically indicated CS in many middle- and high-income countries.[2,3,4] Yet, population caesarean rates above 20% have not been shown to improve perinatal outcomes.[4,5,6] At the other end, many low-and middle-income countries still have population CS rates well below 10%, which is considered indicative of inadequate access to medically-indicated CS.[3,5,6] In addition, large differences in CS rates have been observed between births in the poorest and richest wealth quintiles within many low- and middle-income countries.[7]

This paper is the first in a series three reviewing the epidemiology of caesarean sections, the short-and long-term health effects on women and children, and the key drivers of caesarean sections and the interventions to reduce them. Together with a FIGO position paper endorsed by the International Confederation of Midwives (ICM),[8] and Women Deliver, we call for a concerted action, including by WHO, governments, ministries of health, and healthcare professional organisations, to reverse the caesarean pandemic.

We describe the global, regional and selected country levels, trends, determinants and inequalities in CS. We updated the global and regional estimates of levels and trends in CS per 100 live births during 2000-2015 and assessed the extent to which the country's socioeconomic level of development and health system characteristics were associated with CS rates. We analysed within-country geographic and socioeconomic inequalities in CS rates in the population and on differences of CS rates between health facilities, including private facilities. Finally, we obtained further insights into the need for and use of CS, as well as inequalities, using the Robson classification by women's education in Brazil and China.[9]

Global and regional levels and trends

We updated the WHO and UNICEF databases on population CS and institutional delivery rates with data published before January 1, 2018, derived from household surveys, annual vital statistics and routine statistical surveillance. For household surveys information is collected retrospectively and statistics are computed for usually three or five-year reference periods years preceding the survey. We located all survey data points in the middle of the reference period. Overall 169 countries were included with at least one national data point on CS and live births in health facilities since 2000, accounting for 98.4% of all births in the world in 2015 (Appendix 1). The mean number of data points per country was six and the mean year of the most recent data point was 2013. To obtain global and regional estimates we weighted all data points by the live births for the reference year.[10] We grouped countries into nine regions (Appendix 2). A penalized B-Spline regression model using the Markov Chain Monte Carlo method of multiple imputations for missing data was used to estimate the CS rate levels, trends and uncertainty during 2000-2015 (Appendix 3). We did not extend beyond 2015 as only few countries had a post-2015 data points. The model was only used for the global and regional level and trend estimates.

Globally, the percent of live births by CS was estimated at 21.1% (95% uncertainty range: 19.9-22.4%) in 2015, up from 12.1% (10.9%-13.3%) in 2000 (Figure 1 and Table 1). The average annual rate of increase was 3.7% per year during 2000-2015. The 2015 levels of CS varied greatly between the nine regions, from 4.1% (3.6-4.6%) in West and Central Africa to 44.3% (41.3-47.4%) in Latin America and the Caribbean. Increases in CS rates were observed in all regions during 2000-2015, most rapidly in the Eastern Europe and Central Asia and South Asia regions. The population CS rates increased slowly in West and Central Africa and Eastern and Southern Africa regions (average annual rates of change 2.1% and 2.0% respectively) and were still well below 10% in 2015. In South Asia and Eastern Europe and Central Asia, as well as East Asia and Pacific, the population CS rates more than doubled during 2000-2015 with average annual rates of change exceeding 5%.

Contribution of increasing institutional birth rates

Population CS rates, the proportion of all live births by CS, can also be expressed as the product of the proportion of all live births in the population occurring in any health institution (institutional birth rate) and the proportion of live births within health institutions delivered by CS (intra-institutional CS rate). The intra-institutional CS rate provides additional insights into the epidemiology of CS in countries where a significant proportion of births occur at home, as institutional birth rates vary over time and within countries. We derived the intra-institutional CS rate (CS per 100 live births in health facilities) by dividing the population CS rate by the institutional birth rate. For each region and globally, we computed the relative contribution of changes in institutional delivery rates and intra-institutional CS rates to the trends in population CS rates.

The global increase in CS rates was driven by increases in the percent of births occurring in health institutions (66.5% of the increase during 2000-2015) as well as increases in the CS rate within health institutions (33.5% of the increase in the population CS rate) (Table 1 and Appendix 3). In the regions in sub-Saharan Africa the modest rise in population CS rates was largely to rising institutional birth rates. In Eastern and Southern Africa, the intra-institutional CS rates declined slightly, leading to negative contributions to the change in population CS rates. The trends may suggest that the health facilities are not keeping up with the increased attendance and need for life-saving CS. In South Asia, the doubling of the population CS rate was driven by more women delivering in health facilities, while the intra-institutional CS rates increased slightly from 23.1% in 2000 to 25.1% in 2015.

Disparities between countries

Based on the most recent data, population-based CS rates exceeded 15% of births in 106 of the 169 countries (63%), while 48 countries had levels below 10% (28%). Figure 2 shows the large differences in intra-institutional CS rates, as well as the major spread among countries grouped by institutional delivery rates. Among 85 countries with more than 95% of births occurring in health facilities, the intra-institutional CS rates varied greatly from less than 10% in Turkmenistan (6.3%) and Kyrgyzstan (9.4%) to over 50% in the Dominican Republic (59.3%) and Brazil (56.0%). Among 32 countries with institutional delivery rates of 80-94%, ten countries had intra-institutional CS rates below 10%, while Egypt's rate was as high as 63.0%. Twenty of the 24 countries with institutional delivery rates below 60% had CS rates

below 10%, but six countries had rates over 15%, with the highest rates in Bangladesh (65.2%) and Myanmar (46.3%).

We assessed the associations of the most recent national population CS rate with level of socioeconomic development (gross national income (GNI) per capita)[11] and women's education (secondary enrollment among girls),[12] urbanization (proportion of population living in urban areas),[9] total fertility rate,[9] and health system (physicians per 10 000 population),[12] using linear regression models with the CS rate as dependent variable. The CS rate was significantly higher in countries with higher levels of socioeconomic development as measured through GNI per capita, higher female enrolment in secondary education, higher levels of urbanization, greater physician density and lower fertility (Appendix 4). Restricting the analysis to 104 countries with CS rates over 15%, however, none of the determinants was significantly associated with the CS rate. Among 51 countries with CS rates below 10%, total fertility rate, female enrolment in secondary education and physician density were significantly associated with CS rates, but GNI per capita or urbanization had no significant association with CS rates. In a multivariable regression model of CS rates with all five independent variables, only total fertility rate remained significantly associated with CS rates.

Disparities within countries

We updated a previous study[7] with recent data from Demographic and Health Surveys (DHS)[13] or Multiple Indicator Cluster Surveys (MICS)[14] to examine the effects of household wealth on both population and intra-institutional CS rates for 82 low- and middle-income countries. Table 2 shows the large differences in population CS rates between women in the poorest (median 4.1%, interquartile range [IQR] 1.9-12.0%) and the richest wealth quintile (median 19.1%, IQR 10.6-33.8%). Two-thirds of countries had population CS rates below 10% among the poorest women and 43% of countries had CS rates below 3%. Among 40 countries with national population CS rates below 10%, the median CS rates for were 1.7% and 10.6% among the poorest and richest quintiles, respectively.

Once the women have reached a health facility there are no obstetric reasons to expect a lower CS rate among the poorest women compared to wealthier women. Yet, women in the wealthiest quintile had on average 2.4 times higher CS rates than women in the poorest quintile (8.9% and 21.3%, respectively) (Appendix 5), which shows the major differences in access to CS even after women have reached a health facility. The explanations may include low overall capacity to provide CS in especially rural settings where most women in the poorest quintiles deliver, financial barriers to CS and a role of the private sector in providing CS to wealthier women in mostly urban areas.

Subnational differences are also large. For example, subnational data for the ten countries with the highest number of births during 2010-2015 showed large but variable differences within countries (Appendix 6). Ethiopia's national CS rate was just 2.0%, but Addis Ababa had a CS rate of 21.4%. Nigeria also had a national CS rate of 2.0%, and the states with the highest levels were still well below 10%. Bangladesh, Brazil and United States all had national CS rates well over 25%, but a roughly twofold difference between the administrative unit with the highest and lowest CS rates was still observed.

Within-country differences in China and India were large, with provincial differences in China ranging from 4% to 62% and inter-state differences in India from 7% to 49%.

The median intra-institutional CS rate was 1.6 times higher (IQR 1.2-2.2) in private facilities compared to public facilities: 18.3% (IQR 19.1-36.4) and 11.0 (IQR 6.9-19.9%), respectively, based on survey data from 69 of the 82 low- and middle-income countries. The intra-institutional CS rate in private facilities exceeded 50% of births in 12 countries. In spite of the higher CS rates in private facilities, the public sector still accounted for the largest proportion of CS with a country median 81.0%, IQR 64.6-92.0%), as the majority of births occurred in public facilities. Higher levels in private institutions compared to public health facilities have also been documented in high and upper middle-income countries [15,16], reaching almost universal CS for births to better-off women in private health facilities in Brazil.[17] A systematic review and meta-analysis of 11 studies in high and upper middle income countries indicated that the odds of receiving a CS were on average 1.84 times higher (1.49 to 2.27) in private for-profit hospitals than in non-profit hospitals.[18] Increasing privatization of the obstetric services may therefore lead to further increases in CS rates.

CS according to the Robson classification

The Robson classification provides further information on the need for and use of CS by possible medical indication.[8 19] The Robson system classifies women giving birth in health facilities into 10 groups based on their obstetric characteristics (parity, previous CS, gestational age, onset of labour, foetal presentation and number of foetuses). The size of each group and the CS rate within each group correspond to an expected range. Monitoring CS rates within the Robson groups therefore allows an assessment of clinical practice, including the extent to which the CS rate can be justified.

We examined CS rates by Robson groups in China and Brazil, two countries with very high national CS rates and data disaggregated by maternal education. We used two sources of nationally representative data: (1) individual level data collected through China's National Maternal Near Miss Surveillance System (NMNMSS) covering all births in 438 hospitals in 2012 and 2016[20] and (2) individual-level data collected through the Livebirths Information System (SINASC) of the Brazilian Ministry of Health, covering all live births in health facilities in Brazil in 2015.[21] We adapted Robson's classification because China's data did not include information on whether the labour was induced and created eight mutually exclusive categories (Appendix 8).

CS rates in hospitals were higher in Brazil (55.6% in 2015) than in China (45.7% and 41.3% in 2012 and 2016 respectively) (Appendix 6). In both countries, a large proportion of live births were among women with a uterine scar (contributing to Robson groups 5, 7, 8, 9 and 10): 17.8% in China (2016) and 27.0% in Brazil (2015). Non-cephalic positions (breech or other abnormal lies) and multiple pregnancies accounted for about 5% of births in both countries, while the percentage of births that were singleton, cephalic and premature (36 weeks or earlier) was 5.5% in China 2016 and 9.2% in Brazil. Robson groups making the largest contribution to overall CS rates in both countries were single cephalic births to nulliparous women with a gestation at least 37 weeks (groups 1-2, 39.9% in China 2016 and 35.4% in Brazil 2015) and single cephalic births with a gestation of at least 37 weeks to women with a uterine scar (group 5, 33.9% in China 2016 and 32.7% in Brazil 2015).

Educational differentials in intra-institutional CS rates were much more pronounced in Brazil than in China, particularly among the Robson groups with the lowest need for CS (single cephalic births to nulli- or multiparous women with a gestation at least 37 weeks, groups 1 to 4, Appendix 4). For example, among women in Robson groups 3-4 in Brazil, those with less than 8 years of education had CS rates of 19.4% compared with 54.4% among those with the highest educational achievements. In China in 2016, CS rates in this group were around 16% regardless of educational achievement. Remarkably, as China's CS rates declined in recent years, the substantial educational differentials in CS rates in 2012 nearly disappeared (Figure 3).

Scars due to previous CS are a major indication for CS. The percent of live births with a previous scar increased from 10% to 18% during 2012-2016 in China because of the relaxation of the one child policy and was 27% in Brazil in 2015. The WHO multi-country studies also reported high levels.[19] Scars are therefore a major factor in increasing CS rates and accentuating socioeconomic and other differentials. Also, possible future reductions in CS rates are likely to be slower than increases, because of the relatively large proportion of births that are to women with previous CS. There is now evidence from a few countries of a stabilization or decrease in CS rate, including China[20], USA [22][23] and Western European countries.

Lack of access and overuse

In 2015, an estimated 21.1% or 29.7 million births occurred through CS, which presented almost a doubling since 2000. The differences in CS rates between regions were striking, with a high of 44.3% in the Latin America and the Caribbean region and a low of 4.1% in West and Central African region. CS rates more than doubled in the South Asia region and the Eastern Europe and Central Asia region during 2000-2015. Between- and within-country differences were also very large. The CS rate in the Dominican Republic (58%), was 14 times higher than the average of countries in the West and Central Africa region. In low- and middle- income countries, births in households in the wealthiest quintile had almost five times higher CS rates than those in the poorest quintile. Within large population countries, differences between regions and provinces were often at least five-fold. There may be few common medical interventions with such great differences between and within countries and regions.

There are several limitations. First, we were unable to obtain recent data for all countries and for a small proportion of countries we only had one data point during 2000-2015. We used additional data points in the nineties to obtain better information on trends. We however had data for mode of delivery for 98.4% of the world's births. Second, we relied heavily on survey data for low- and middle-income countries. The recall of CS section in survey may be biased, but validation and reliability studies in multiple countries have shown that recall of CS is good in most settings.[24-26] All CS rates were expressed per 100 live births in line with the standard definition. A better measure would be CS rates for all births, including stillbirths, but such data were not available.

We used the population CS rate thresholds of 10% and 15% as an indication of poor access and overuse of CS. The optimal threshold is difficult to determine. A recent systematic review of the evidence of the association between CS rates and mortality concluded that CS rates improved maternal, newborn and infant survival until a threshold ranging from 9% to 16%, but that socioeconomic factors may be driving

the ecological relationship between CS rates and mortality.[2] Our study showed that in Brazil and China, both countries with very high CS rates and high coverage of institutional deliveries, there were only small differences in the prevalence of obstetric problems (abnormal lies) between the three education groups (about 5-6%), multiple pregnancies (1.5-2.2%) and modest differences in the prevalence of prematurity (5-10%). WHO multi-country studies in 2004-08 and 2010-11 showed similar rates of breech and other abnormal fetal presentations, multiple pregnancies and prematurity.[19] Within these high-risk categories CS is an important and leading intervention, but not the only intervention. Optimal CS rates will vary depending on the prevalence of the obstetric problems and the capacity of the health facility to implement high-quality obstetric interventions. A 10% or slightly higher threshold however appear to be in the right ballpark, given prevalence of complications.

Drivers of high and increasing CS rates include factors related to childbearing women, families, communities, and the broader society, factors related to health professionals, and those related to healthcare systems, poor-quality care, disrespectful care, financing, and culture.[27] Reasons for women to demand caesarean without a medical indication include fear of labour pain, or of effects such as pelvic floor damage, urinary incontinence, or reduced quality of sexual life. Cultural concepts, and myths also play a role, as do perception of care quality, logistics, costs, and agency. Previous negative experiences of vaginal birth and of care are also influences. Most women who prefer a caesarean perceive it to be safer.[28]

The physician/obstetrician is the key actor in choice of delivery mode in most countries. Logistics and financial incentives, fear of litigation, and the demands of women are factors with which healthcare providers contend. Society in general – the legal profession in particular – may believe that caesareans are protective, contrary to scientific evidence. Consequently, practitioners may be more likely to be sued for complications during vaginal delivery than for unnecessary caesareans.

The current caesarean pandemic is of concern for medical education: young colleagues have become experts in caesarean but are losing the wider art of obstetrics and vaginal assisted deliveries. Staff must be supported to develop the skills to provide quality support for both normal birth and emergency care.

Caesarean Section is an essential emergency intervention that can save lives of women and newborns. The CS rate is an indicator with one of the largest disparities between the rich and the poor. This analysis shows that many women in low- and middle-income countries still do not have adequate access to CS. CS rates are increasing mainly driven by increases in institutional delivery rates but are still well below 10% in many countries. In several countries, poor women have CS rates close to 0%, implying that some women die because they cannot access life-saving surgery during labour. At the other end, there is strong evidence of major and increasing over-use of CS in many other countries in all parts of the world.

Contributors

TB, CR and MT conceptualized the paper. TB wrote a first draft and all authors contributed to revisions. DYM led the estimation work. TB, AJDB and AH ran the survey data analyses by wealth quintile and private sector. CR, FCB, MY, LJ and DLRN conducted the Brazil and China analyses using the Robson classification. All authors reviewed and approved the final manuscript.

Declaration of interest

We have no conflict of interest.

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The global epidemiology of Caesarean Sections: major increases and <u>wide</u> disparities ~~, over-use and inadequate access~~

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Key messages

- Global CS rates are high and increasing. In 2015, an estimated 21.8% or 30.7 million births occurred through CS, which represented almost a doubling since 2000. The differences in population CS rates between regions were huge, with a high of 43.7~1~% in the Latin America and the Caribbean region and a low of 4.2~1~% in West and Central African region.

- There are large disparities in the CS rate has ~is an indicator with one of the largest disparities~ between and within countries. Population CS rates are increasing in all regions, but are still well below 10% in sub-Saharan Africa. Many poor women in low- and middle-income countries still do not have adequate access to CS. ~Population CS rates are increasing, driven by increases in institutional delivery rates, but are still well below 10% in many countries~. In several countries, poor women have CS rates close to 0%, implying that ~some~ women and babies die because they cannot access life-saving surgery during labour.

- At the other end, there is strong evidence of massive over-use of CS in many countries. CS rates were still increasing in most regions with rates well over 15% by 2015, driven by extremely high CS rates among wealthier women, high rates in private facilities and by high proportions of women at low risk of obstetric complications giving birth by CS.

Abstract

This Lancet Series paper, one of three on the <u>high rate of</u> ~~pandemic of~~ Caesarean Section~~s~~ (CS~~s~~), describes the global, regional and selected country levels, trends, determinants and inequalities in CS. Based on data from 169 countries representing 98.<u>4</u>~~2~~% of the world's births, we estimated that 21.8% (uncertainty range 20.5-23.1%) or 30.7 million births occurred through CS in 2015, representing almost a doubling since 2000 <u>(11.7%; 10.4-13.0%)</u>. The differences in CS rates between regions <u>in 2015</u> were <u>tenfold</u>~~huge~~, with a high of 4<u>3.7</u>~~1~~% <u>(40.3-47.1%)</u> in the Latin America and the Caribbean region and a low of 4.<u>2</u>% <u>(3.7-4.7%)</u> in <u>the</u> West and Central African region. The global and regional increases were ~~largely~~ driven <u>both by increasing coverage of births by health facilities</u> ~~by higher CS rates within health facilities~~ (58.<u>4</u>% of the global increase)~~,~~ <u>and higher CS rates within health facilities (41.6%), with considerable variation between regions.</u> ~~except in sub-Saharan Africa and South Asia where increasing coverage of births by health facilities was the main reason for the increase in population CS rates. Intra-institutional CS rates were particularly low in West and Central Africa (6.1%).~~ <u>Based on the most recent data, population-based CS rates exceeded 15% of births in 63% of 169 countries, while 28% countries had CS rates below 10%.</u> ~~Country~~ <u>National</u> CS rates varied from 0.6% in South Sudan to 58.1% in the Dominican Republic. Within-country disparities in CS rates were also very large, with a six-fold difference in CS rates between births in the richest and poorest quintiles in low- and middle-income countries, markedly higher CS rates among low obstetric risk births in Brazil and China and private facilities having 1.<u>6</u>~~8~~ times higher CS rates than public facilities. The CS rate is an indicator with one of the largest disparities between and within countries. There is strong evidence of poor access for women giving birth in many countries, especially if they are economically disadvantaged, and of ~~massive and~~ increasing over-use of CS in many other countries.

Introduction

Caesarean section (CS) is a life-saving intervention for women and newborns when complications occur, such as antepartum haemorrhage, fetal distress, abnormal fetal presentation and hypertensive disease. CS is the most common major surgical intervention in many countries.[1] Rates of CS have been rising during the last three decades to levels well above recommended CS rates of 10-15%, driven by major increases in non-medically indicated CS in many middle- and high-income countries.[2-4] At the other end, many~~ost~~ low-and middle-income countries still have population CS rates well below 10%, which is considered indicative of inadequate access to medically-indicated CS.[3,5,6] Furthermore, large differences in CS rates have been observed between births in the poorest and richest wealth quintiles within many low- and middle income countries.[7]

This ~~series~~ paper is the first in a three-part Series on the ~~, one of three on the pandemic~~ high rate of CSs in which we ~~,~~ describe~~s~~ the global, regional and selected country levels, trends, determinants and inequalities in CS. We updated the global and regional estimates of levels and trends in CS per 100 live births during 2000-2015 and assessed the extent to which the country's socioeconomic level of development and health system characteristics were associated with CS rates. We focused on within-country geographic and socioeconomic inequalities in CS rates in the population and on differences of CS rates between health facilities, including private facilities. Finally, we obtained further insights into the need for and use of CS, as well as inequalities, using the Robson classification by women's education in Brazil and China.[8]

~~Methods~~

~~For the estimates of global and regional levels and trends we updated the WHO and UNICEF databases on population CS rates with data published before January 1, 2018, derived from household surveys, vital statistics and routine statistical surveillance. Only national data were used. There were 174 countries, accounting for 98.2% of all births in the world in 2015, with on average six data points during 2000-2017. For 168 countries, we had data points on CS, births in health facilities and births in the population. To obtain global and regional estimates we weighted all data points by the estimated live births for the reference year.[8] We grouped countries into nine regions (Appendix 1). A penalized B-Spline regression model using the Markov Chain Monte Carlo method of multiple imputations for missing data was used to estimate the CS rate levels, trends and uncertainty during 2000-2015 (Appendix 2). We did not extend beyond 2015 as only few countries had a data point after that. The model was only used for the global and regional level and trend estimates. All country analyses were based on the most recent data points.~~

~~Population CS rates are defined as the product of proportion of all live births in the population occurring in any health institution (institutional birth rate) and the proportion of live births within health institutions delivered by CS (intra-institutional CS rate). The intra-institutional CS rate provides additional insights into the epidemiology of CS in countries where a significant proportion of births occur at home, as institutional birth rates vary over time and within countries. We derived the intra-~~

institutional CS rate (CS per 100 live births in health facilities) by dividing the population CS rate by the institutional birth rate. For each region and globally, we computed the relative contribution of changes in institutional delivery rates and intra-institutional CS rates to the trends in population CS rates.

We assessed the associations of the population CS rate with level of socioeconomic development (gross national income (GNI) per capita) and women's education (secondary enrollment among girls),[10] urbanization (proportion of population living in urban areas), total fertility rate,[9] and health system (physicians per 10 000 population),[11] using linear regression models with the CS rate as dependent variable. We then conducted separate analyses for countries with low CS rates (defined as less than 10%) and high CS rates (15% or higher).[3]

We assessed within-country inequalities in population CS rates by administrative region for the ten countries with the highest number of births in 2015. The effects of household wealth on both population and intra-institutional CS rates were examined for 82 low- and middle-income countries with data from Demographic and Health Surveys (DHS)[12] or Multiple Indicator Cluster Surveys (MICS)[13] conducted since 2010, updating the data set from a previous study.[7] In addition, we examined the CS rates in public and private facilities in a subset of 28 countries with surveys from 2013.

The Robson classification for institutional deliveries provides further information on the need for and use of CS by possible medical indication.[8,14] The Robson system classifies women into 10 groups based on their obstetric characteristics (parity, previous CS, gestational age, onset of labour, foetal presentation and number of foetuses). The size of each group and the CS rate within each group correspond to an expected range. Monitoring CS rates within the Robson groups therefore allows an assessment of clinical practice, including the extent to which the CS rate can be justified.

We examined CS rates by Robson groups stratified by maternal education using two sources of data: (1) individual level data collected through China's National Maternal Near Miss Surveillance System (NMNMSS) covering all births in 438 hospitals in 2012 and 2016[15] and (2) individual level data collected through the Livebirths Information System (SINASC) of the Brazilian Ministry of Health, covering all live births in health facilities in Brazil in 2015.[16] We adapted Robson's classification because China's data did not include information on whether the labour was induced and created eight mutually exclusive categories (Appendix 4).

The analyses of survey data were conducted in Stata 15.2 and SAS.

Results

Global and regional Levels and trends

For the estimates of global and regional levels and trends We we updated the WHO and UNICEF databases on population CS and institutional delivery rates with data published before January 1, 2018, derived from household surveys, annual vital statistics and routine statistical surveillance. For household surveys information is collected retrospectively and statistics are computed for usually three or five-year reference periods years preceding the survey. We located all survey data points in the middle of the

reference period. Overall 169 countries were included with at least one national data point on CS and live births in health facilities, accounting for 98.4% of all births in the world in 2015 (Appendix 1). Only national data were used. There were 174 countries, accounting for 98.2% of all births in the world in 2015, The mean number of data points per country was six and the mean year of the most recent data point was 2013. with on average six data points during 2000-2017. For 168 countries, we had data points on CS, births in health facilities and births in the population. To obtain global and regional estimates we weighted all data points by the estimated live births for the reference year.[9] We grouped countries into nine regions (Appendix 21). A penalized B-Spline regression model using the Markov Chain Monte Carlo method of multiple imputations for missing data was used to estimate the CS rate levels, trends and uncertainty during 2000-2015 (Appendix 32). We did not extend beyond 2015 as only few countries had a data point after that. The model was only used for the global and regional level and trend estimates. All country analyses were based on the most recent data points.

Population CS rates are defined as the product of proportion of all live births in the population occurring in any health institution (institutional birth rate) and the proportion of live births within health institutions delivered by CS (intra-institutional CS rate). The intra-institutional CS rate provides additional insights into the epidemiology of CS in countries where a significant proportion of births occur at home, as institutional birth rates vary over time and within countries. We derived the intra-institutional CS rate (CS per 100 live births in health facilities) by dividing the population CS rate by the institutional birth rate. For each region and globally, we computed the relative contribution of changes in institutional delivery rates and intra-institutional CS rates to the trends in population CS rates.

Globally, the percent of live births by CS was estimated at 21.9% (95% uncertainty intervalrange: 20.5-23.1%) in 2015, up from 11.7% (10.4%-13.0%) in 2000 (Figure 1 and Table 1). The average annual rate of increase was 4.2% per year during 2000-2015.

The 2015 levels of CS varied greatly between the nine regions, from 2.93.5% (2.33.0-3.94.1%) in West and Central Africa to 43.72.9% (40.339.2-47.146.5%) in Latin America and the Caribbean. Increases in CS rates were observed in all regions during 2000-2015, most rapidly in the Eastern Europe and Central Asia and South Asia regions. The population CS rates hardly increased slowly in West and Central Africa and Eastern and Southern Africa regions (average annual rates of change 2000-2015 2.51.0% and 2.0%1.3 respectively) and were still well below 10% in 2015. The intra-institutional CS rates declined and were particularly low in West and Central Africa (6.1% in 2015). In South Asia and Eastern Europe and Central Asia, the population CS rates more than doubled during 2000-2015 with average annual rates of change exceeding 5%., driven by more women delivering in health facilities, while the intra-institutional CS rates remained just above 20% (Table 1).

Contribution of increasing institutional birth rates

Population CS rates, the proportion of all live births by CS, can also be expressed asare the product of the proportion of all live births in the population occurring in any health institution (institutional birth rate) and the proportion of live births within health institutions delivered by CS (intra-institutional CS rate). The intra-institutional CS rate provides additional insights into the epidemiology of CS in countries

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where a significant proportion of births occur at home, as institutional birth rates vary over time and within countries. We derived the intra-institutional CS rate (CS per 100 live births in health facilities) by dividing the population CS rate by the institutional birth rate. For each region and globally, we computed the relative contribution of changes in institutional delivery rates and intra-institutional CS rates to the trends in population CS rates.

The global increase in CS rates was driven by increases in the percent of births occurring in health institutions (58.4% of the increase during 2000-2015) as well as increases in the CS rate within health institutions (41.6% of the increase in the population CS rate)(Table 1). In the West and Central Africa and the Eastern and Southern Africa regions the intra-institutional CS rates declined, leading to negative contributions to the change in population CS rates, and were particularly low in West and Central Africa (7.3% in 2015). In these regions the small rise in population CS rates was fully due to by rising institutional birth rates. This may suggest that the health facilities are not keeping up with the increased attendance and need for life-saving CS. In South Asia, the doubling of the population CS rate was driven by more women delivering in health facilities, while the intra-institutional CS rates remained stable at just above 20% (Table 1).

Disparities between countries

Based on the most recent data, ~~National~~ population-based CS rates exceeded 1540% of births in 106 of the 169 countries (63%), while 48one in six (27) countries had levels below 105% (28%). Figure 2 shows the ~~enormous~~ large differences in intra-institutional CS rates, as well as the major spread among~~within the~~ countries grouped by institutional delivery rates. Among 85 countries with more than 95% of births occurring in health facilities, ~~where population and institutional rates are almost equal,~~ the intra-institutional CS rates varied greatly from less than 10% in Turkmenistan (6.3%) and Kyrgyzstan (9.4%) to over 50% in the Dominican Republic (59.3%) and~~,~~ Brazil (56.0%).~~, Turkey (54.6%) and Venezuela (53.0%).~~ Among 32 countries with institutional delivery rates of 80-94%, ten countries had intra-institutional CS rates below 10%, while Egypt's rate was as high as 63.0%. Twenty~~Most~~ of the 243 countries with institutional delivery rates below 60% had CS rates below 10%, but six countries had rates over 15%, with the highest rates in~~including~~ Bangladesh (65.2%) and~~,~~ Myanmar (46.3%)~~and Sudan (38.8%)~~.

In countries where large proportions of women deliver in health facilities but the probability that a woman delivers by CS is very low, such as in the Central Asian Republics, Burkina Faso and the Democratic Republic of Congo. This may be indicative of lack of institutional capacity to provide CS to women in need, especially if CS rates are well below 10%. Similarly, there are countries with low institutional delivery rates and very high CS rates in institutions such as Bangladesh, Myanmar, Pakistan and Guatemala. Although this may suggest the existence of good referral systems for high risk pregnancies, the much greater CS rates among rich compared to poor women giving birth in health institutions also suggest major inequalities in access to CS (see below).
We assessed the associations of the national population CS rate with level of socioeconomic development (gross national income (GNI) per capita)[10] and women's education (secondary enrollment

among girls),[10] urbanization (proportion of population living in urban areas),[9] total fertility rate,[9] and health system (physicians per 10 000 population),[11] using linear regression models with the CS rate as dependent variable. ~~We then conducted separate analyses for countries with low CS rates (defined as less than 10%) and high CS rates (15% or higher).[2]~~

The most recent national CS rate was significantly ~~(at the 1% level)~~ higher in countries with higher levels of socioeconomic development as measured through GNI per capita, higher female enrolment in secondary education, higher levels of urbanization, greater physician density and lower fertility (Appendix 4~~3~~). Restricting the analysis to 104 countries with CS rates over 15%, however, none of the national determinants was significantly associated with the CS rate. Among 51 countries with CS rates below 10%, lower ~~total~~ fertility ~~rate (beta = -1.282, (95% confidence interval: -1.795 to -0.768), p < .001)),~~ higher female enrolment in secondary education ~~(beta = 0.037 (0.014 - 0.060), p = .002)~~ and higher physician density ~~(beta = 0.219 (0.596 -0.378), p=.008)~~ were significantly associated with higher CS rates, but GNI per capita or urbanization had no significant association with CS rates. In a multivariable regression model of CS rates with all five independent variables, only total fertility rate remained significantly associated with CS rates ~~(beta=-1.37 (-2.35 - -0.39), p=.008, R² = 3.63)~~.

Disparities~~Inequalities~~ within countries

We examined the effects of household wealth on both population and intra-institutional CS rates for 82 low- and middle-income countries with data from Demographic and Health Surveys (DHS)[12] or Multiple Indicator Cluster Surveys (MICS)[13] conducted since 2010, updating the data set from a previous study.[7] Table 2~~3~~ ~~National surveys in 82 low and middle-income countries conducted from 2010~~ showed the large differences in population CS rates between women in the poorest (median 4.1%, interquartile range [IQR] 1.9-12.0%) and the richest wealth quintile (median 19.1%, IQR 10.6-33.8%). Two-thirds of countries had population CS rates below 10% among the poorest women and 43% of countries had CS rates below 3%. ~~(Table 3)~~. Among 40 countries with national population CS rates below 10%, t~~The~~ median CS rates for ~~31 countries with national CS rates below 10%~~ were 1.7% and 10.6% among the poorest and richest quintiles, respectively.

~~The intra-institutional CS rates also varied greatly between women in the poorest and richest quintiles with median of 8.9% (IQR 5.2 16.3%) and 21.3% (IQR 11.6 37.4%). Large gaps were observed in countries at both low and high population CS rates. The median CS rates for 31 countries with national CS rates below 10% were 1.7% and 10.6% among the poorest and richest quintiles respectively. Among 40 countries with national CS rates of 15% or higher, the country median CS rates were 14.8% and 39.4% among the poorest and richest quintiles respectively. Similar differences were observed for intra-institutional CS rates (Appendix 5~~4~~).~~ Once the women have reached a health facility there are no obstetric reasons to expect a lower CS rate among the poorest women compared to wealthier women. Yet, women in the wealthiest quintile had on average 2.4 times higher CS rates than women in the poorest quintile (8.9% and 21.3%, respectively) (Appendix 5), which shows the major differences in access to CS even after women have reached a health facility. The explanations may include low overall capacity to provide CS in especially rural settings where most women in the poorest quintiles deliver,

financial barriers to CS and a role of the private sector in providing CS to wealthier women in mostly urban areas.

Subnational differences are also large. Reviewing ~~S~~subnational data for the ten countries with the highest number of births during 2010-2015 show~~ed~~ large but variable differences within countries (Appendix 6~~Table 2~~). At the lower end, Ethiopia's national CS rate was just 2.0%, but Addis Ababa had a CS rate of 21.4%. Nigeria also had a national CS rate of 2.0%, and the states with the highest levels were still well below 10%. At the higher end, Bangladesh, Brazil ~~andand~~ United States~~A~~ all had national CS rates well over 25%, but a roughly twofold difference between the ~~increase from the lowest and highest~~ administrative unit with the highest and lowest CS rates was still observed. Within-country differences in China and India were large, with provincial differences in China ranging from 4% to 62% and inter-state differences in India from 7% to 49%.

~~Private sector~~

For 69 of the 82 low- and middle-income countries we ~~We~~ examined~~d~~ the CS rates by facility ownership.~~in public and private facilities in a subset of 28 countries with surveys from 2013. The probability of birth by CS is much greater in private-for-profit than in public health facilities. Among 28 low- and middle-income countries with a survey since 2013~~ ~~T~~the median intra-institutional CS rate was 1.6 times higher (IQR 1.2-2.2) in private facilities compared to public facilities: 18.3% (IQR 19.1-36.4) and 11.0~~8.8%~~ in public institutions (IQR 6.9~~6.4~~-19~~6.9~~1%) ~~and 20.4% (IQR 16.1-58.5%) in private-for-profit institutions~~ respectively. The intra-institutional CS rate in private facilities exceeded 50% of births in 12~~eight~~ countries.~~ Seven countries had both private and public intra-institutional CS rates below 10% (Appendix 7~~5~~). The private-public facility CS rate ratio was 1.8 (country median).~~ In spite of the higher CS rates in private facilities, the public sector still accounted for the largest proportion of CS ~~in all but two of the 28 countries~~ with a country~~(~~ median 81.0~~77.5~~%, IQR 64.6~~63.9~~-92~~87~~.0%), as the majority of births occurred in public facilities.

~~Private-for-profit facilities had on average 1.8 times higher CS rates than public facilities in low- and middle-income countries.~~ Higher levels in private institutions compared to public health facilities have also been documented in high and upper middle-income countries [17 18], reaching almost universal CS for births to better-off women in private health facilities in Brazil.[19] A systematic review and meta-analysis of 11 studies in high and upper middle income countries indicated that the odds of receiving a CS were on average 1.84 times higher (1.49 to 2.27) in private for-profit hospitals than in non-profit hospitals.[20] Increasing privatization of the obstetric services may therefore lead to further increases in CS rates.

CS according to the Robson classification

The Robson classification~~for institutional deliveries~~ provides further information on the need for and use of CS by possible medical indication.[8 14] The Robson system classifies women giving birth in health

facilities into 10 groups based on their obstetric characteristics (parity, previous CS, gestational age, onset of labour, foetal presentation and number of foetuses). The size of each group and the CS rate within each group correspond to an expected range. Monitoring CS rates within the Robson groups therefore allows an assessment of clinical practice, including the extent to which the CS rate can be justified.

We examined CS rates by Robson groups ~~and maternal education~~ in China and Brazil, two countries with very high national CS rates and data disaggregated by maternal education. We ~~stratified by maternal education~~ us~~ed~~ing two sources of nationally representative data: (1) individual level data collected through China's National Maternal Near Miss Surveillance System (NMNMSS) covering all births in 438 hospitals in 2012 and 2016[15] and (2) individual-level data collected through the Livebirths Information System (SINASC) of the Brazilian Ministry of Health, covering all live births in health facilities in Brazil in 2015.[16] We adapted Robson's classification because China's data did not include information on whether the labour was induced and created eight mutually exclusive categories (Appendix 8~~4~~).

CS rates in hospitals were higher in Brazil (55.6% in 2015) than in China (45.7% and 41.3% in 2012 and 2016 respectively) (Appendix 6). In both countries, a large proportion of live births were among women with a uterine scar (contributing to Robson groups 5, 7, 8, 9 and 10): 17.8% in China (2016) and 27.0% in Brazil (2015). Non-cephalic positions (breech or other abnormal lies) and multiple pregnancies accounted for about 5% of births in both countries, while the percentage of births that were singleton, cephalic and premature (36 weeks or earlier) was 5.5% in China 2016 and 9.2% in Brazil. Robson groups making the largest contribution to overall CS rates in both countries were single cephalic births to nulliparous women with a gestation at least 37 weeks (groups 1-2, 39.9% in China 2016 and 35.4% in Brazil 2015) and single cephalic births with a gestation of at least 37 weeks to women with a uterine scar (group 5, 33.9% in China 2016 and 32.7% in Brazil 2015).

Educational differentials in intra-institutional CS rates were much more pronounced in Brazil than in China, particularly among the Robson groups with the lowest need for CS (single cephalic births to nulli- or multiparous women with a gestation at least 37 weeks, groups 1 to 4, Appendix 4). For example, among women in Robson groups 3-4 in Brazil, those with less than 8 years of education had CS rates of 19.4% compared with 54.4% among those with the highest educational achievements. In China in 2016, CS rates in this group were around 16% regardless of educational achievement. Remarkably, as China's CS rates declined in recent years, the substantial educational differentials in CS rates in 2012 nearly disappeared (Figure 3).

Scars due to previous CS are a major indication for CS. The percent of live births with a previous scar increased from 10% to 18% during 2012-2016 in China because of the relaxation of the one child policy and was 27% in Brazil in 2015. The WHO multi-country studies also reported high levels.(ref) Scars are therefore a major factor in increasing CS rates and accentuating socioeconomic and other differentials. Also, possible future reductions in CS rates are likely to be slower than increases, because of the relatively large proportion of births that are to women with previous CS. There is now evidence from a few countries of a stabilization or decrease in CS rate, including China[15], USA [21 22] and Western European countries.

Discussion

In 2015, an estimated 21.8% or 30.7 million births occurred through CS, which presented almost a doubling since 2000. The differences in CS rates between regions were striking, with a high of 41% in the Latin America and the Caribbean region and a low of 4% in West and Central African region. CS rates more than doubled in the South Asia region and the Eastern Europe and Central Asia region during 2000-2015.

Between- and within-c~~C~~ountry differences were also very large~~huge~~. The CS rate in the ~~the~~ Dominican Republic (58%) ~~with the highest recorded rates of CS of 58% in the Dominican Republic~~, was almost 14~~more than 16~~ times higher than the average of countries in the West and Central Africa region. ~~The within-country differences were also very large.~~ In low- and middle- income countries, births in households in the wealthiest quintile had almost five times higher CS rates than those in the poorest quintile. Within large population countries, differences between regions and provinces were often at least five-fold. There may be few common medical interventions with such great~~massive~~ differences between and within countries and regions.

The evidence for overuse in many countries is strong. In more than half of 169 countries (54%) CS rates exceeded 15%, and levels of socioeconomic development, urbanization, physician density and fertility were not associated with the national CS rate.

~~It could be expected that countries in which more women give birth in health facilities also have higher intra-institutional CS rates, because higher institutional delivery rates and higher CS rates in institutions are both associated with a higher level of development of the health system: greater availability of delivery facilities and greater capacity of health facilities to provide CS rates. The results showed that this is only partly true. There are many countries where large proportions of women deliver in health facilities but the probability that a woman delivers by CS is very low, such as in the Central Asian Republics, Burkina Faso and the Democratic Republic of Congo. This may be indicative of lack of institutional capacity to provide CS to women in need, especially if CS rates are well below 10%. Similarly, there are countries with low institutional delivery rates and very high CS rates in institutions such as Bangladesh, Myanmar, Pakistan and Guatemala. Although this may suggest the existence of good referral systems for high risk pregnancies, the much greater CS rates among rich compared to poor women giving birth in health institutions also suggest major inequalities in access to CS.~~the existence of ~~strong incentives for CS among rich women, leading to unnecessary CS.~~

~~In spite of the modest increase, there is still a major lack of access to CS in many low- and middle-income countries. CS rates in 54~~8 ~~of the 169~~8 ~~countries (28~~35%) ~~were below 10% and 34 countries (21%) had national rates below 5%, including 23 countries in sub-Saharan Africa. Among the countries with low CS rates (<10%) lower fertility, higher physician density and better levels of women's education were associated with higher CS rates. The~~ modest ~~almost negligible~~ increase~~s~~ ~~in population CS rates in West and Central Africa and in Eastern and Southern Africa despite rising institutional delivery rates is~~

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worrying. Intra-institutional CS rates declined, which suggests that the health facilities are not keeping up with the increased attendance and need for life-saving CS.

Once the women have reached a health facility there are no obstetric reasons to expect a lower CS rate among the poorest women compared to wealthier women. Yet, women in the wealthiest quintile had on average six times higher CS rates than women in the poorest quintile (1.7% and 10.6% in low- and middle-income countries 82 countries, respectively) which shows the major differences in access to CS even after women have reached a health facility. The explanations include low overall capacity to provide CS in especially rural settings where most women in the poorest quintiles deliver, financial barriers to CS and a role of the private sector in providing CS to wealthier women in mostly urban areas.

The evidence for overuse in many countries is strong. In more than half of 169 countries (54%) CS rates exceeded 15%, and levels of socioeconomic development, urbanization, physician density and fertility were not associated with the national CS rate. Within-country differences however were still large. The median CS rates among women in the highest wealth quintile in 40 low- and middle-income countries with national CS rates of 15% or higher had 2.7 times higher CS rates than women in the poorest quintile (39.4% and 14.8% respectively). The data among the low obstetric risk categories in the Robson classification in Brazil showed that more educated women had a much greater chance of giving birth by CS than women with low levels of education. China, however, showed a decline during 2012-2016 of the use of CS for women at low risk which erased the differences by the women's level of education.

Private-for-profit facilities had on average 1.8 times higher CS rates than public facilities in low- and middle-income countries. Higher levels in private institutions compared to public health facilities have also been documented in high and upper middle-income countries [17,18], reaching almost universal CS for births to better-off women in private health facilities in Brazil. [19] A systematic review and meta-analysis of 11 studies in high and upper middle income countries indicated that the odds of receiving a CS were on average 1.84 times higher (1.49 to 2.27) in private for-profit hospitals than in non-profit hospitals. [20] Increasing privatization of the obstetric services may therefore lead to further increases in CS rates.

Scars due to previous CS are a major indication for CS. The percent of live births with a previous scar increased from 10% to 18% during 2012-2016 in China because of the relaxation of the one child policy and was 27% in Brazil in 2015. The WHO multi-country studies also reported high levels. Scars are therefore a major factor in increasing CS rates and accentuating socioeconomic and other differentials. Also, possible future reductions in CS rates are likely to be slower than increases, because of the relatively large proportion of births that are to women with previous CS. There is now evidence from a few countries of a stabilization or decrease in CS rate, including China [16], USA [21,22] and Western European countries.

Supply factors are likely to play an important role, such as economic considerations for providers, given the differences by wealth quintile within countries. The fear of malpractice-related issues may also lead to high CS rates and could lead to differences between the poor and the rich, as litigation may be more likely among wealthy, educated women and their partners.   There may also be differences in the demand for CS by women which are accommodated by the providers. Other factors may play a role in explaining country differences, such as e.g. level of privatization of health services, health insurance

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~~policies or demand factors, but were not examined in detail because such data are not routinely available.~~

There are several limitations to our study. First, we were unable to obtain recent data for all countries and for a small proportion of countries we only had one data point during 2000-2015. We used additional data points in the nineties to obtain better information on trends. We however had data for mode of delivery for 98.~~4~~2% of the world's births. Second, we relied heavily on survey data for low- and middle-income countries. The recall of CS section in survey may be biased, but validation and reliability studies in multiple countries have shown that recall of CS is good in most settings.[23-25] All CS rates were expressed per 100 live births in line with the standard definition. A better measure would be CS rates for all births, including stillbirths, but such as data were not available.

We used the population CS rate thresholds of 10% and 15% as an indication of poor access and overuse of CS. The optimal threshold is difficult to determine. A recent systematic review of the evidence of the association between CS rates and mortality concluded that CS rates improved maternal, newborn and infant survival until a threshold ranging from 9% to 16%, but that socioeconomic factors may be driving the ecological relationship between CS rates and mortality.[2] Our study showed that in Brazil and China, both countries with very high CS rates and high coverage of institutional deliveries, there were only small differences in the prevalence of obstetric problems (abnormal lies) between the three education groups (about 5-6%), multiple pregnancies (1.5-2.2%) and modest differences in the prevalence of prematurity (5-10%). WHO multi-country studies in 2004-08 and 2010-11 showed similar rates of breech and other abnormal fetal presentations, multiple pregnancies and prematurity.[14] Within these high-risk categories CS is an important and leading intervention, but not the only intervention. Optimal CS rates will vary depending on the prevalence of the obstetric problems and the capacity of the health facility to implement high-quality obstetric interventions. A 10% or slightly higher threshold however appear to be in the right ballpark, given prevalence of complications.

Drivers of high and increasing CS rates include factors related to childbearing women, families, communities, and the broader society, factors related to health professionals, and those related to healthcare systems, poor-quality care, disrespectful care, financing, and culture.[3] Reasons for women to demand caesarean without a medical indication include fear of labour pain, or of effects such as pelvic floor damage, urinary incontinence, or reduced quality of sexual life. Cultural concepts, and myths also play a role, as do perception of care quality, logistics, costs, and agency. Previous negative experiences of vaginal birth and of care are also influences. Most women who prefer a caesarean perceive it to be safer.[5]

The physician/obstetrician is the key actor in choice of delivery mode in most countries. Logistics and financial incentives, fear of litigation, and the demands of women are factors with which healthcare providers contend. Society in general – the legal profession in particular – may believe that caesareans are protective, contrary to scientific evidence. Consequently, practitioners may be more likely to be sued for complications during vaginal delivery than for unnecessary caesareans.

The current caesarean pandemic is of concern for medical education: young colleagues have become experts in caesarean but are losing the wider art of obstetrics and vaginal assisted deliveries. Staff must be supported to develop the skills to provide quality support for both normal birth and emergency care.

Caesarean Section is an essential emergency intervention that can save lives of women and newborns. The CS rate is an indicator with one of the largest disparities between the rich and the poor. This analysis shows that many women in low- and middle-income countries still do not have adequate access to CS. CS rates are increasing mainly driven by increases in institutional delivery rates but are still well below 10% in many countries. In several countries, poor women have CS rates close to 0%, implying that some women die because they cannot access life-saving surgery during labour. At the other end, there is strong evidence of massive over-use of CS in many other countries, with the highest rates occurring in middle-income countries in Latin America and the Caribbean region. ~~CS rates were still increasing in most regions with rates well over 15% by 2015. Private facilities have even higher rates than public facilities and women at low-risk of obstetric complications had very high rates of CS with potentially harmful consequences.~~

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Contributors

TB and CR conceptualized the paper. TB wrote a first draft and all authors contributed to revisions. DYM led the estimation work. TB, AJDB and AH ran the survey data analyses by wealth quintile and private sector. CR, FCB, MY, LJ and DLRN conducted the Brazil and China analyses using the Robson classification. All authors reviewed and approved the final manuscript.

Declaration of interest

We have no conflict of interest.

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Manuscript: THELANCET-D-18-02022, The global epidemiology of Caesarean Sections: major increases and disparities, over-use and inadequate access

1. As promised, here are the full set of reviews (including the statistician's report). Recognising that we do not wish this to be reported as a research article, you will still find the statistician's comments helpful in your revision and to ensure full information is included.

We revised the article to meet the Series format.

Reviewer #1: I passionately believe that we perform too many caesarean sections in the UK and in many high income countries. However, if we are to do anything about this, we need to engage in a meaningful debate with clinicians and women to explore their concerns and work with them to do something about it. The tone of this paper, with its clear prejudices and implication of blame on obstetricians is not the way to do this. The use of emotive language such as "a pandemic of caesarean sections", "massive over use of caesarean sections" will not help engage clinicians in this debate, but alienate them. The data in this paper are important and need to be read, but this can be done without the element of blame which permeates the text. The other problem with this first paper is that there is no clear articulation of why there are concerns about increasing use of caesarean section. This comes in later papers in the series but does not make for a very helpful read if the papers are read in order.

We removed the use of the word pandemic and inserted a general introduction in the introduction of this paper.

This paper describes the global epidemiology of CS, which is vital. However, the reasons for these rates and the potential interventions which might affect these are very different in countries with a high rate of caesarean section and those with a very low rate of caesarean section. In higher rate caesarean section countries the concerns are about potential overuse. In very low resource countries, where the CS rate is very low, and we believe babies are dying or suffering as a consequence of having little access to CS, the issues are completely different and are around the availability of resources, trained staff, hospital equipment etc. Conflating them in this series is rather unhelpful unless we clearly separate out the two scenarios. In the background to this paper part of the justification for the work is given as the "pandemic" of CS. If the focus is really on the high rate of CS in many then presenting the overall epidemiology is helpful but the rest of the series can focus on the high and increasing rates of caesarean section which will make the narrative hang together more coherently.

The focus of the series is indeed on the high rate of CS in the world, but as the reviewer noted the first paper presents the overall epidemiology. We edited the paper here and there to make clear that this is the case and also made this specific in the introduction.

There is a lack of distinction between CSs that are done before the onset of labour and those done during labour. The rates are different, and the ratio will vary between different settings. This aspect of the epidemiology is important, because different strategies will be needed for each type of CS if we are to decrease CS rates. I know that these data are difficult to obtain but that does not mean the issue should be largely ignored in discussing and interpreting the data.

We have had extensive debate among the authors about the value of this distinction. The epidemiological studies only provide weak evidence, but the question on the timing of the CS has now been introduced in many country surveys. We briefly summarize this issue in the Discussion.

In the methods section on page 4 I think the authors have confused the definition of population CS rates. They state that the denominator is all live births within an institution, which is clearly not correct for many countries where large numbers of women don't deliver within institutions. It should be all live births.

The sentence is to explain the population CS rate as the product of institutional delivery rate and intra-institutional CS rate. This is now further clarified in the text.

This paper includes the Robson groups to categorise women into groups which have different risks of CS and uses them to assess the extent to which the observed rate "can be justified". This is inappropriate. The groups, as defined, will have different risks of CS - but this is not the same as using this as a measure of the appropriateness of CS. This grouping system takes no account of intrapartum events. And as the authors then illustrate the groupings are unhelpful in this context because national data are rarely collected in enough granularity to allow the groups to be defined in this way.

A further assumption that needs challenging is the statement in the Discussion (third paragraph, final sentence) that states "… the much greater CS rates amongst rich compared to poor women giving birth in health institutions also suggests the existence of strong incentives for CS amongst rich women, leading to unnecessary CS". Why is this unnecessary? In countries where there are shortages of health professionals and women have to pay for surgery, why are the CSs done in the rish women an indication of over-treatment, rather than the low CS rate in poor women being a sign of under-treatment?

We agree that the data should not be overinterpreted and revised the text to stress the inequality in access to CS.

I found Figure 3 difficult to understand. The format of the blue dots for China 2012 is not helpful. Either have a Figure for China comparing 2012 and 2016 and a separate Figure for Brazil, or have three figures in one - but trying to abbreviate in this way is confusing.

Revised the figure in an effort to make clearer

Reviewer #2: This paper aims to evaluate (at global, regional, country levels) caesarean rates, trends, determinants, and inequalities. The authors have done primary research to summarise these data. Findings gleaned from the Abstract include: global rate (22%), global trend (doubled in 15 years), global determinants of this doubling (both increase proportion of births in facility and increase in CS rate within the facility), marked variation in rates by region and by country, and variation within country by socioeconomic status. Authors conclude that women have too little access to caesarean in some countries, while in other countries there is overutilization of caesarean delivery.

Introduction
Would structure it to match the abstract and then have this lead the structure of the rest of the paper
We revised the introduction to match the series and paper 1.

Methods
Page 4 population C-section rates are defined - I would put the terms first, with the explanation of the term in parentheses. Also if the variable of interest is intra-institutional C-section rate, and this was derived, then this sentence should lead that paragraph.

We re-organized this section to align with the Series format, and improved the definitions.

Page 5 The whole methods section needs clarification - what is the PICO research question, what is the primary hypothesis. It isn't clear where the authors are doing primary research, or where they are reviewing and summarising what is already published. It's not clear when you describe trends or variation, if there is any data analysis to see if this is statistically significant or not. The methods should explain the rationale for why the categorisations in the tables and figures were chosen, and why the focus on China and Brazil (data were available/easy to obtain, or these two countries most important because they contribute the most deliveries to the world?)

The methods section is now integrated with the results, which should help explain the choices that were made. Statistical interpretations was also strengthened throughout.

Results
1st paragraph final line '(…in the population C-section rate)' should be deleted.

Now that I am reading the Results, I think there should be a question posed in the Introduction could be: if increase in C-section rate is found, what are the drivers, proportion of births occurring in health institutions or increase in C-section rate within health institution or both.

The introduction describes that the paper assesses the extent to with development and health system are associated with CS rates, but did not assess the drivers of change in CS rates.

Can the authors perform a test of trend?

We added uncertainty intervals. We also provided the full series with uncertainty intervals by region in the Appendix.

1st paragraph of results could be subtitled 'overall population rate', next paragraph 'variation by region', then 'variation by country', then 'variation within countries', then 'Variation by health Facility type'.

We revised the paper structure with new subheadings along these lines.

I don't understand the phrase 'at the 1%.' If this refers to P value, it should be in the methods section, not results.
We deleted this phrase and refer to the appendix for details

Last paragraph - last two lines need clarification.

Not sure which lines the reviewer refers to. We did revise the results section to make it less complex and align with the series format.

Table 3 It makes sense to me as an obstetrician in a well-developed country that under 10% represents women not accessing CS, whilst > 15% (or could argue >20%) represents overutilization - I wish this categorisation was more consistent throughout the paper and figures

We changed the results to be more consistently focused on these two cutoff points.

Discussion

The first paragraph of any Discussion should highlight all the key findings of the paper (answering the key research questions in the introduction), the second paragraph should offer the Authors' interpretation and possible solutions, and the third limitations and strengths. I would suggest overall that the Discussion be written much more concisely.

GO THROUGH

We already know the CS rate is too high in our well-developed countries; we also know that access is a problem in less-developed countries. This paper to me provides proof for these statements, which is really great - these results are relevant, timely and important. The interpretation to me falls short though. As a reader, I would want to have stated clearly the answers to: what the drivers are for the "global pandemic of CS'? What the barriers are to access? Why are the rates so high in some regions/countries? Why is there such variation more than any other surgical procedure? Why do rich women get more CS in low and middle income countries? To reduce the global pandemic where should the world put the resources - just in China and Brazil or everywhere? How does the world get all countries to CS rates > 10% to save mothers and babies lives? Need to differentiate answers that are known (with references), answers that the current research has found (link to tables, figures), and answers that are hypothesised by these expert Authors.

The reviewers raises many relevant questions of interpretation. Some of these are answered better in paper 2 and 3 of the Series. Others we chose to not speculate too much – there are several strong predictors of variation in CS rates, but one has to be careful in interpreting the results as was also made clear by reviewer 1.

Page 8
1st paragraph -the first sentence shows that the C-section rate overall has doubled in brackets (is this significant?) As a reader I would like to know in what region it increased the most compared to the least. 2nd paragraph I don't think 'huge' or 'very large' are scientific terms. Reword as 'significant' if it is.

Revised the language and added uncertainty ranges.

Page 9
1st paragraph needs to differentiate their authors hypotheses from other references. The authors should explain whether it is socioeconomic status or urban/ rural that influences C-section rates.

This is a difficult question to answer, given the strong association between place of residence and SES. Further analyses with double disaggregation (e.g. comparing poor urban women to rich rural women) may throw some light on this issue, but this was beyond the scope of this paper.

2nd paragraph does not add any interpretation to the results already stated above.

We moved some of the text to the results on private sector.

3rd paragraph again does not add interpretation; the message is that repeats CS rates are high and could be reduced by increasing clinical pathways to VBAC; however, reducing the first caesarean is more important.
We shortened this section to results but kept the integration of results in different sections.

4th paragraph needs references.
We omitted this section in the revised version

Table 1 this is really interesting looking at trends over time in regions. For example America has seen a huge increase in caesarean over time almost all of which is due to institutional C-section rate, as compared to increases in middle east, south Asia and east Asia, most of which is related to more women delivering in institutions

Table 2 shows geographical variation within countries, which is not new information.

Table 3 shows a similar increase in caesarean rate by SES regardless of low or high C-section rate countries.

Figure 1 great.

Figure 2 does the methods explain how the authors categorized institutional birth rate.

Figure 3 I don't understand the column titles and rational e for categorisation of years, and I'm not sure why rates are so high for the multipara single cephalic term no scar.
We improved the graph titles and explained the education categories in the text. The surprising high rates among multipara single cephalic term no scar is indeed notable.

Reviewer #3: I have read the paper reviewing changes in C-section rates over the period 2005-3015 with great interest. I am very grateful to the authors for undertaking the task of putting all the data together giving us something meaningful to quote for many years to come.
I have some minor issues which I hope they will be able to address.
The overall description of the data often begs for more context. Although the paper has a clear limitations section on what couldn't be included, other variables which are quite easily available could have been included and might have added more of a story behind some of the interaction. MMR for example could explain more some of the outliers such as The Dominican Republic. In addition, the recent wave of user fees removal in particular in SSA could also be looked at alongside the changes in the rates to give more context. I'm not advocating trend analysis but either more discussion around it when explaining the results or including dummy on whether CS is free at point of delivery in the regression models. These can all give more context in the comparison between countries.
We tried to gather comparable data on financial barriers to institutional delivery and CS, but were not successful in obtaining such information for the majority of countries.

It is not clear where all the data beyond the DHS was taken from and how confident of the overall quality the authors feel. It would be useful to add a web appendix with all the data and data sources included.

We added data and the list of data sources to the Appendix.

In particular the data on China, which is explored more in depth, has been marred by issues in the past (see Sufang at al for example) around the government's manipulation of the data. I wonder how much the authors trust the Chinese data.
 We are comfortable with the data. The second author spend a year in China with the team.
The wealth index needs more explanation. Was this the standard variable included in the DHS? If that's the case that is misleading mainly if the discussion includes rural Vs urban description. The DHS calculates the wealth index at national level ignoring the different weight that assets have by residence. If that's the case the limitation should be listed in the final section as otherwise we keep on producing reports which are describing an inaccurate picture of wealth distribution in the country.

We used the computations of the University of Pelotas which aligns with the DHS approach.
The current methodology used by DHS does take into account the differences in assets (both specific assets for urban/rural areas and the different importance they might have). The index is calculated separately for urban and rural areas, and then using a regression model, it is rescaled into a single number for both strata.

The result for Bangladesh also asks for further clarification and actually to highlight more drawbacks for C-section. As Parkhurst highlighted about a decade ago the high rates of CS in hospitals can create a stigma for women delivering in facilities which might counteract the quest for institutional deliveries. I haven't seen any other study looking at this more recently and possibly mentioning it in the paper might inspire some researchers.

It is an interesting qualitative study. We decided to not include it as the situation in Bangladesh has changed a lot since the study was done, and it would take a whole paragraph to introduce the thinking underlying the Parkhurst paper while we were aiming to reduce the length of the discussion.

Reviewer #4: This is an important article in a series of articles on caesarean section that provides substantial information on the worldwide cesarean pandemic and the inequalities between countries and regions and within countries as well as their determinants. The article is well written, the methods section is clear, the results are well presented and the discussion appropriate. We recommend its approval.

Reviewer #5: The authors have clearly undertaken a comprehensive analysis to determine the current epidemiology of caesarean sections on a global scale from a few different angles. This is both a strength and weakness of the manuscript, because the variety of analyses are difficult to describe in replicable detail given the word limits of a published manuscript. The web appendix allows for extra information, however, it is unclear if this was the most recent version of the appendix as it was dated 6th April and contained a comment in capitals which appeared to be for the authors to add information to.

My major comment regarding the manuscript in its current form (even with the web appendix) is that the key data are not presented well in places and the statistical methods are not described well enough to be able to critique properly.

Methods

The number of countries used for analysis is not clear. The abstract states "169 countries representing 98.2%..." whereas the methods state "There were 174 countries, accounting for 98.2% of all births in the world in 2015, with on average six data points during 2000-2017. For 168 countries,…". Was it 168 or 169 or 174 countries?

The correct number of countries is 169 with data points for Caesarean section and institutional delivery rates. We put this number consistently.

The ordering of the methods section is confusing as the reader is introduced to "data points" before a definition is provided of what the data points are. Statistical models are introduced mid-paragraph and are lost in the thread.
We defined data points in the main text.

Should rates in the first sentence of the methods be replaced with numbers?
Rates is correct.
What is meant by "on average" six data points..., mean, median or mode?
Mean, corrected
The description of data points available and used in analysis is not very clear. If data beyond 2015 was not used, then should it even be mentioned?
We did use surveys beyond 2015 but because the data is retrospective the data point refers to 2015 or earlier
What does "All country analyses were based on the most recent data points." mean? What analyses were done at the country level?
Deleted the sentence.

What were the eligibility criteria for "data points" to be included in the analysis? For example, there are data published from Singapore, why was this not eligible?
We did not have data for institutional deliveries and Caesarean section for Singapore.

What is meant by "estimated" in the phrase estimated live births? Estimated by whom?
The UN Population Division reference is given at the end of the sentence.

Definitions are provided for population CS rates as a product of institutional birth rate and intra-institutional CS rate. Then Intra institutional CS rate is defined as dividing population CS rate by institutional birth rate. This does not actually state what the numerator and denominator are for the institutional birth rate nor intra institutional CS rate. Perhaps there is some redundancy here?

The definitions are now provided more clearly in the text.

The most current version of stata is 15.1 as of the 8th May 2018, there is no 15.2. Which version of SAS was used?

This is omitted in the new layout, but mentioned in the Appendix section on methods.

More information is required regarding the imputation methods. How many imputations were performed, what imputation models were used, which covariates were included in imputation models etc? This information are key statistically and should not be hidden away in the online appendix. What diagnostics were run on the models to assess stability?

We have added further details on these in the Appendix.

More information is required regarding the spline model, how many knots were used? What assumptions does the model make about non-linearity? How were the weights incorporated, was it as inverse probabilities?

We have added further details on these in the Appendix.

What does the following mean "we computed the relative contribution of changes in institutional delivery rates and intra-institutional CS rates to the trends in population CS rates"? How was the relative contribution defined?

We added a footnote to the table with the computations referring to the Appendix explanation of the computations.
Computations: contributions to change $P2-P1 = (D2-D1)*(I2+I1)/2 + (I2-I1)*(D2+D1)/2$; Proportional contributions for changes in institutional delivery rates: $((D2-D1)*(I2+I1)/2)/(P2-P1)$ and intra-institutional CS rate: $((I2-I1)*(D2+D1)/2)/(P2-P1)$ where P1,P2: population CS rate; D1,D2: institutional delivery rate; I1, I2: intra-institutional CS rate, years 2000 and 2015.

Where was data on GNI, and urbanisation obtained? Why were the list of variables presented chosen as predictors of CS? Were they also imputed if missing? How were temporal changes incorporated into this linear regression? i.e. how were dependencies over time accounted for? How was it decided a linear regression was appropriate? No mention of transformations or centring or standardisation of data, was this done? What separate analyses were conducted for countries with high and low CS rates? Do the authors mean a test for effect modification was conducted?

Added references for GNI and urbanization.
The variables were chosen based on availability of comparable data.
No temporal changes were included, the analysis was only done for the CS rates in 2015.
Data were examined for non-linear relationships, in the whole set and subsets stratified according to levels of CS. No transformations were done. The same model was applied to the high and low CS rate countries.

In the paragraph commencing "We assessed within-country inequalities…" there are a number of different and complex analyses referred to which each in their own right would be worthy of their own manuscript. The level of detail required to explain them is out of the scope of the present manuscript which detracts from their importance. Are all of these analyses required for the present manuscript? How does a story come out from all of them given that different countries and different years are being analysed for different aspects?
We included this descriptive section to show the reader that the large differences between countries are only part of the picture and that within almost every country major subnational and major socioeconomic difference occur. It is part of the epidemiological story. We agree that further analysis would be needed to understand better why these differences occur and that the answers are likely to differ between countries.

What were the 10 countries referred to in this sentence "We assessed within-country inequalities in population CS rates by administrative region for the ten countries with the highest number of births in 2015."? Why only the highest 10 countries? How changeable from year to year are the 10 countries with the highest number of births? How were within country regional data obtained? From the same source as national data or from further sources? How were temporal changes accounted for?

These 10 countries do not change much from year to year, but the choice is arbitrary. We picked these countries to show that subnational differences are generally large. The data are from national surveys – the same source – but for a few countries the data were obtained from the literature and a reference is provided. No temporal changes were taken into account.

The previous study referred to here "The effects of household wealth on both population and intra-institutional CS rates were examined for 82 low- and middle-income countries…" was only published 6 months ago. Is an update really necessary yet? If so, then more details are required over data availability and analysis, i.e. how many new surveys were available after the previous study? Does this further analysis change the interpretation of the data from the previous study, if not, then perhaps this is one analysis which does not need to be in the present manuscript.

We were able to add 11 countries and 7 updated data sets, as the previously published study only used data released up to mid 2014. We revised the text of the section but kept it as it is an essential element of the effort to show the wide multi-dimensional diversity in CS rates.

In this sentence "In addition, we examined the CS rates in public and private facilities in a subset of 28 countries with surveys from 2013." there is not justification given for the year restriction, is this from 2013-2015? Nor justification to the restriction to 28 countries? What was it about these countries that made them be analysed for this research question? For consistency could this analysis be considered for the 10 countries with the highest number of births in 2015.

For consistency we included more country surveys – from 2010 onward, same as the analysis of inequalities – we ended up with 70 countries with surveys with the relevant information.
We did not have this information on the private sector in a comparable manner for all 10 countries mentioned above.

In this sentence "We examined CS rates by Robson groups stratified by maternal education using two sources of data:…" there is not a justification given for stratifying the analysis by maternal education, for what reason was this done? How representative were the 438 Chinese hospitals of all Chinese hospitals? How many hospitals are there in China?
Maternal education was the only stratifier available in the Brazil and China data sets. This in fact was unique, most countries do not have data disaggregated by SES. We added this in the text.

Results- Levels and trends
Initial results are presented abruptly without context. It would be helpful to present total sample size of non-missing data, median and IQR of years of data per country. This would be followed by total sample size analysed (i.e. how many data points were imputed). Given later comments also some mention of data extrapolation, i.e. how many were extrapolated?
Details on interpolation, extrapolation and missing data are provided in the Appendix

Given the methods of analysis are Bayesian, shouldn't the term credibility interval be used, what is an uncertainty range? A non-linear model (the spline) was fit to the data but a linear increase "on average" (is this mean?) per year in presented, is there a linear or non-linear trend in CS over time?

We used uncertainty interval and further details have been added to make this clearer. Note that the change in the rate of CS was computed using two end data points in a linear context though the overall trend in CS overtime exhibits a non-linear pattern.

Is there a way of testing the difference between 2000 and 2015 levels to state if the levels of CS had significantly increased? That is instead of saying "hardly increased" there might be no evidence for a change?
We have now provided uncertainty intervals in Table 1 and also show the full time series in the Appendix. We instead performed a regression analysis using global estimate of the non-linear trend to determine the rate of increase in CS over time, and found that it in fact significantly increased by 3.7% per year from 2000 to 2015.

Why was it chosen to focus on South Asia levels in the text? This sentence is out of order.
Because of its large numbers of births – sentence edited

Results- Disparities between countries
Which year's data is being referred to in this paragraph? This first paragraph is difficult to read and does not have any table to refer to. All of the country data would be useful to refer to in a supplementary table. There are no measures of uncertainty presented here, why is that?
Revised this section. These are based on the most recent data points (added text), the reference is to the Figure, and the new appendix with all data provides detail for the interested readers. For surveys we could include confidence intervals, but not for countries where data are based on registration systems. Therefore, we chose not to include uncertainty.

"Among 85 countries with more than 95% of births occurring in health facilities, where population and institutional rates are almost equal…" does this mean there are also countries where more than 95% of births occur in health facilities but where population and institutional rates are not equal? This appears an odd finding to highlight.
Removed this part of the sentence

"…but six countries had rates over 15%, including Bangladesh (65.2%), Myanmar (46.3%) and Sudan (38.8%)" why were these three of the six chosen to be presented in the text?
These were the highest – noted in text

"The most recent national CS rate was significantly (at the 1% level) higher in countries with higher levels of socioeconomic development as measured through GNI per capita, higher female enrolment in secondary education, higher levels of urbanization, greater physician density and lower fertility (Appendix 3)." Does most recent national CS rate refer to 2015? If not perhaps a sentence could detail to which year it does refer as well as the sample size of how many countries were analysed. Was linearity between dependent and independent variables tested for statistically, I note from the table that GNI was log transformed, what justification was there for a log transform over another transform? Why was the term "significantly (at the 1% level)" used instead of presenting a p-value?
The numbers of countries are provided in the Appendix table. We used log GNI in line with many other publications; also the coefficients would be very small if we used GNI. We present the P-values in detail in the appendix..

"Among 51 countries with CS rates below 10%, total fertility rate…" why in this sentence are "beta" coefficients presented but not in the previous sentence? How should these be interpreted?
We now refer the reader for all results to the Appendix.

"In a multivariable regression model with all five independent variables…" with which dependent variable? Why was the R squared presented only for this model? R squared is a value between 1 and 0, does this refer to a value of 0.03? The model does not explain the data well, were diagnostics carried out?
We added CS rates as dependent to the text.
The model R squared was .363, this was a typo, apologies.
We refer to the Appendix for detailed results.

Results - inequalities within countries

"National surveys in 82 low and middle-income countries…" unclear why 82 countries. No details given for which years the surveys come from. Unclear why medians are presented for this description compared to other analyses where means are presented. Why was a statistical model and rate ratio with p-value not presented?
The 82 countries have surveys conducted since 2010 – now explained in text. We presented medians in line with the previous study on 71 countries which we updated.

Results-private sector
"Among 28 low- and middle-income countries with a survey since 2013" with what kind of survey? Why the year restriction? Again why were medians presented here and why no statistical model?
DHS or MICS national survey, as before.
We added surveys from 2010 to be consistent with the previous section and revised the results.

Results- Robson classification
No p-values or statistical models to quantify the relationships? Statistical justification for stratifying by education?
Education was the available socioeconomic stratifier which made these data unique. Numbers are very large for both countries, hence no statistical models were run.

Table 1
How is "average annual rate of change" calculated, does average refer to mean? Unclear how to interpret contribution to change, particularly negative values. Measures of uncertainty should be presented for estimates of CS rate.
We added a footnote to explain the computations.
Negative values are now explained in the text.
Uncertainty was added to the table for population CS rates.

Table 2
Measures of uncertainty around rates should be presented. It is misleading to only present the lowest and highest rates with absolute and relative differences because these (the lowest and highest) may be outliers. Boxplots would show how varied within a country the rates were. Even within a unit the rates may differ between institutions dramatically. Unclear if rates are weighted by population. Rate is per what?

We moved the table to the appendix. All rates are per live births and weighted. We did not have the space to elaborate but wanted to use this as an illustration and reminder of large differences within countries.

Figure 1
"Uncertainty range" is labelled "CI" (confidence interval or credibility interval?)

We have corrected this in all the figures as uncertainty interval.

"Total births" should read "total live births"
Corrected

"Raw data" (i.e. including imputed data) are difficult to see and interpret. When data were imputed, which data point is presented on this figure? Box plots of country data would be easier to interpret. Similarly, the trend line is quite difficult to see and the measure of uncertainty is hard to see because of the scale.
The regional figures are even more difficult to read.

We have improved figures and can be found in the Appendix. In addition, we included new figures for the two regions in Africa using different scales. Global and regional level estimates of CS and uncertainty intervals are also provided in the Appendix.

Figure 2

Box plots would better represent the data. Sample size for each group of institutional birth rate would aid interpretation.
The samples sizes are given in the added database for the appendix (see comments above)

Figure 3
Years of education are presented but the word "education" does not appear in the figure or title so figure does not stand alone.
Added

Are the three stratifications of births mutually exclusive? i.e. are the first three bars for women with uterine scar, the next for those without, and the last three for all other births? Or do the first three include those with and without uterine scar? Sample size (% of all births) would aid interpretation. The sample sizes are included in the Web Appendix.

Web appendix 1
Country groupings are difficult to read because there are no commas separating their names.
Corrected

Web appendix 2
A very important point regarding the "data points" that were analysed to obtain the global estimates is not mentioned until the web appendix. That is, some data are obtained by surveys which utilise recall

over a time period of up to five years. It is not clear if the source data were scrutinised to obtain yearly estimates or if another technique was used to disaggregate the data to annual estimates.

We have provided raw data in the Appendix.

A second key point hidden in the appendix is that data for 2000 and 2015, if not available as data points in their own right, were obtained by "extrapolation" (one assumes by the explanation that the use of the term imputation is incorrect). This process has not been explained in detail that it might be replicated, for example was this model based, was there uncertainty around these extrapolations, was this done somehow separately for each country? Why was a linear extrapolation chosen when a non-linear spline was used for the overall trend?

In addition to raw data added, further details have been added in the Appendix to make this cleared. Details on the different scenarios utilized to impute missing data have been provided in the appendix.

Web appendix 3
Terminology is confusing. Bivariate and full regression models are used. i.e. make clear unadjusted and adjusted. Why are adjusted estimates only provided for countries with CS<10%? All unadjusted models have different sample sizes which does not allow for comparison between them. Consider use of complete case analysis or multiple imputation?
Still unclear how to interpret the estimates.
We used unadjusted and adjusted models as terms.
There was no association with any variable for countries at CS rates of >=15% or higher.

Figure should have proper labels on x and y axes.
Done in footnote

Web appendix 5
Measures of uncertainty should be added.
There are data points from the most recent surveys. We do not have confidence limits for all surveys at this point.

Web appendix 6
Presented numbers are percentages? If so then label as such.
OK.

An R2 of 0.000 is presented. This is incorrect, it should read <0.001.

Other comments
What was missing from the manuscript (would fit in the appendix) was a listing by country of some characteristics of their data, for example how many data points were used in analysis, how many were imputed, perhaps source of data. i.e. as all of the data for the Robson classification are shown in the appendix.
Done

Consider use of a flow diagram for inclusion of data in different analyses to detail number of years of data available etc.

Further minor comments

Some language is sensationalist, for example the use of the words "huge" and "massive" in the abstract, "enormous differences" in the results.
Removed
The word "live" should be added in front of births throughout, or use a different terminology to shorten.
Done
Discussion could mention what impact the lack of information on stillbirths and their omission from numerator and denominator would have.
Included

_____

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Dr Jocalyn Clark
Executive Editor
The Lancet

Figure

Table 1: Population Caesarean Section per 100 live births and intra-institutional CS rate per 100 live births in health facilities, with annual rates of change and respective contribution to changes over time, by region, 2000-2015.

Region	Population CS rate					Intra-institutional CS rate			Contribution to change (%	
	2000.0	95% UR	2015	95% URI	AARC	2000	2015	AARC	Inst. del	Inst. CS rate
Global	12.1	10.9-13.3	21.1	19.9-22.4	3.7	22.5	27.1	1.2	66.5	33.5
West and Central Africa	3.0	2.4-3.5	4.1	3.6-4.6	2.1	6.6	7.2	0.5	75.2	24.8
Eastern and Southern Africa	4.6	3.4-5.9	6.2	5.0-7.5	2.0	12.0	11.1	-0.5	127.3	-27.3
Middle East and North Africa	19.0	14.9-23.0	29.6	25.5-33.7	3.0	28.9	33.9	1.1	63.4	36.6
South Asia	7.2	5.8-8.5	18.1	16.7-19.4	6.1	24.3	25.5	0.3	94.6	5.4
East Asia and Pacific	13.4	11.0-15.9	28.8	26.3-31.2	5.1	20.4	31.2	2.8	44.4	55.6
Latin America and Caribbean	32.3	29.2-35.3	44.3	41.3-47.4	2.1	37.2	47.0	1.6	26.0	74.0
Eastern Europe and Central Asia	11.9	8.7-15.2	27.3	24.1-30.6	5.5	13.3	27.5	4.8	13.2	86.8
North America	24.3	22.8-25.8	32	30.5-33.5	1.8	24.5	32.6	1.9	-4.4	104.4
Western Europe	19.6	18.1-21.2	26.9	25.4-28.5	2.1	20.1	27.6	2.1	0.7	99.3

Notes: CS is Caesarean section rate per 100 live births; Inst. is institutional; UR is uncertainty range; AARC is average annual rate of change, computed as ln(P2/P1)/15. For details computation, Appendix 3.

Table 2: Median Caesarean Section (CS) rate per 100 births in the population by wealth quintile, 82 low- and middle-income countries overall, and among low (CS rate < 10%) and high (>=15%) CS rate countries, DHS and MICS conducted 2010 or later.

Countries		National average (%)	Quintile 1 (poorest) (%)	Quintile 2 (%)	Quintile 3 (%)	Quintile 4 (%)	Quintile 5 (richest) (%)
All	median	10.1	4.1	6.9	9.4	11.9	19.1
N=82	Q1	4.5	1.9	2.4	3.6	5.9	10.6
	Q3	21.1	12.0	17.9	21.6	25.2	33.8
CS < 10%	median	4.4	1.7	2.3	3.5	5.7	10.6
N=40	Q1	3.2	0.9	1.2	2.1	3.4	8.0
	Q3	6.3	2.5	3.5	4.7	7.0	14.0
CS >=15%	median	26.2	14.8	19.9	26.8	28.6	39.4
N=31	Q1	19.8	10.6	16.3	21.0	23.8	33.0
	Q3	30.7	25.9	25.6	33.2	39.9	53.8

Q1 and Q3 are first and third quartile; DHS: Demographic and Health Surveys; MICS: Multiple Indicator Cluster Survey

Figure 1. Estimated levels and trends of Caesarean Section per 100 live births in the population globally and by region, 2000-2015.
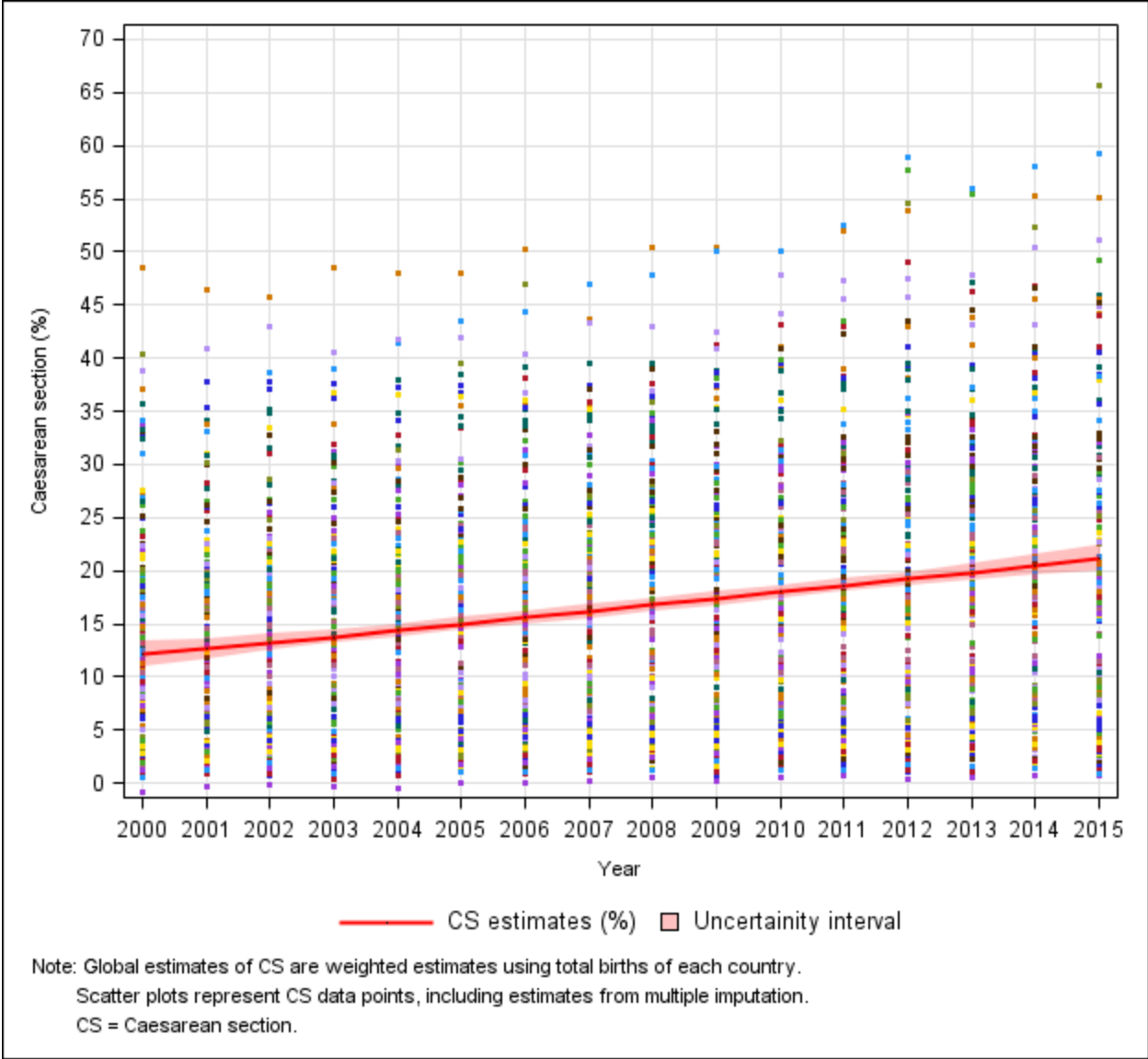

Note: Global estimates of CS are weighted estimates using total births of each country.
   Scatter plots represent CS data points, including estimates from multiple imputation.
   CS = Caesarean section.

Eastern and Southern Africa

Western and Central Africa

Middle East and North Africa

South Asia

East Asia and Pacific

Eastern Europe and Central Asia

Latin America and Caribbean

North America

Western Europe

Caesarean section (%)

Year

CS estimates (%)   Uncertainity interval

Note: Regional estimates are weighted using total births of each country in the region.
   Scatter plots represent CS data points, including estimates from multiple imputation.
   CS = Caesarean section.

3

Figure 2: Intra-institutional CS rates per 100 live births by institutional birth per 100 births in the populations grouped into four categories (below 60%, 60-79%, 80-95% and 95% and higher), based on the most recent data point 2000-2015 in 169 countries (each dot represents one country).
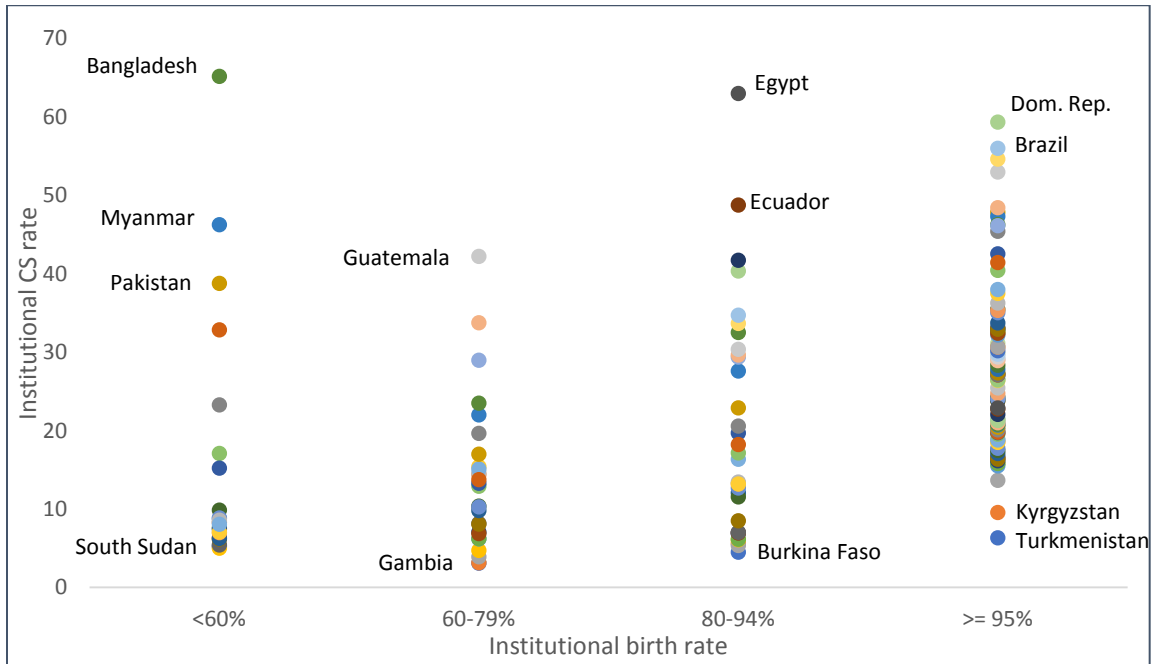
Dom. Rep. = Dominican Republic

Figure 3: Caesarean section rates per 100 live births among single cephalic births at term and all other live births, by level of woman's education, China (438 hospitals in 2012 and 2016) and Brazil (all hospital data 2015).
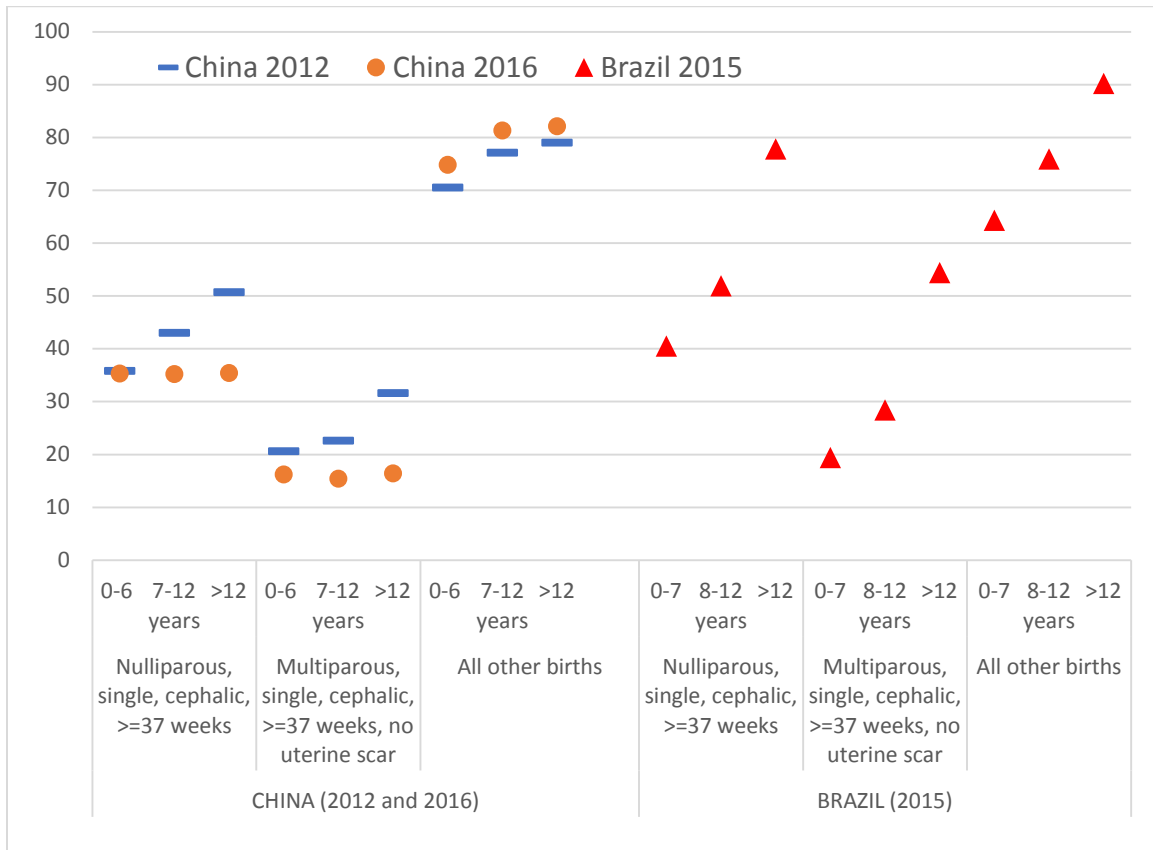
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