BMJ Open

Time trends in caesarean section rates and associations with perinatal and neonatal health: a population-based cohort study of 1 153 789 births in Norway

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To cite: Laine K, Pay AD, Yli BM. Time trends in caesarean section rates and associations with perinatal and neonatal health: a population-based cohort study of 1 153 789 births in Norway. *BMJ Open* 2023;**13**:e069562. doi:10.1136/bmjopen-2022-069562

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2022-069562).

Received 27 October 2022
Accepted 24 January 2023

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ABSTRACT

Objectives To study caesarean section (CS) rates and associations with perinatal and neonatal health in Norway during 1999–2018.
Design Population-based cohort study.
Setting Medical Birth Registry of Norway.
Participants 1 153 789 births and 1 174 066 newborns.
Methods CS, intrapartum, perinatal and neonatal mortality rates expressed as percentages (%) or per mille (‰) with 95% CIs.
Primary and secondary outcome measures CS rates in the Robson Ten-Group Classification System; intrapartum, perinatal and neonatal mortality rates.
Results The overall CS rate increased from 12.9% in 1999 to 16.7% in 2008 (p<0.001), and then reduced to 15.8% in 2018 (p<0.001). The largest reductions were observed in Robson groups 2 and 4. In Robson group 2, the planned CS rate decreased from 9.6% in 2007–2008 to 4.6% in 2017–2018, the intrapartum CS rate decreased from 26.6% in 2007–2008 to 22.3% in 2017–2018. In Robson group 4, the planned CS rate decreased from 16.1% in 2007–2008 to 7.6% in 2017–2018, and the intrapartum CS rate decreased from 7.8% in 2007–2008 to 5.2% in 2017–2018.
The intrapartum fetal mortality rate decreased from 0.51 per 1000 (‰) in 1999–2000 to 0.14‰ in 2017–2018. Neonatal mortality decreased from 2.52‰ to 1.58‰.
Conclusions CS rates in Norway increased between 1999 and 2008, followed by a significant reduction between 2008 and 2018. At the same time, fetal and neonatal mortality rates decreased. Norwegian obstetricians and midwives have contributed to maintaining a low CS rate under 17%. These findings indicate that restricting the use of CS is a safe option for perinatal health.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The 20-year study period enabled us to describe changes in caesarean section (CS) rates over time.
⇒ Robson Ten Group Classification is internationally widely used making the comparison to other settings possible.
⇒ The data is large and reliable and enables to study infrequent events such as adverse fetal and newborn outcomes: intrapartum, perinatal and neonatal mortality and low Apgar scores.
⇒ We did not have access to CS indications and therefore we could not distinguish the main reasons for CS: fetal hypoxia/asphyxia and labour dystocia.
⇒ We could not analyse the impact of maternal request on decision for CS.

INTRODUCTION

Caesarean section (CS) is a life-saving surgical procedure performed when illness or complications occur during pregnancy and labour, but it also entails short-term and long-term health challenges for both the mother and the child.

In 1985 the WHO recommended that a CS rate exceeding 15% is unlikely to improve maternal or perinatal outcomes,[1] and recent analyses have found that maternal and neonatal mortality rates may be lowest when the overall CS rate is around 19%.[2] Despite the WHO recommendations and knowledge of harmful health effects from unnecessary CS use, the rates have increased worldwide, with rates >30% being reported in 2018 in Latin America and the Caribbean (42.8%), East Asia (33.7%), Australia and New Zealand (33.5%), Northern Africa (32.0%), West Asia (31.7%), North America (31.6%) and Southern Europe (30.1%).[3 4] However, the average CS rate in low-income countries was 8.2%.[3] Non-clinical factors such as professional practice styles, increasing pressures related to malpractice and economic, organisational and cultural factors mostly explain the increased CS rates, and changes in maternal characteristics such as higher age and obesity only play minor role in this development.[5 6] The Robson Ten-Group Classification System has been proposed to stratify CS rates to facilitate their monitoring and reduction when considered necessary.[7]

Awareness of restricting CS use to avoid unnecessary surgery has been a patient safety issue in quality-improvement projects in Norwegian maternity units. The main aim of this study was to determine the time trends of CS rates in Norway using the Robson Ten-Group Classification System. We also aimed to study the associations between CS rates and perinatal and neonatal outcomes.

METHODS

Ethical approval and patient consent

This population-based cohort study formed part of the PURPLE study, which assesses complications associated with pregnancy, labour and delivery in Norway. The study was conducted in accordance with the Norwegian Health Research Act, and the researchers only had access to anonymised data.

Design and data sources

The data analysed in this population-based registry study were obtained from the Medical Birth Registry of Norway (MBRN). In Norway, it has been mandatory to notify the MBRN of all births, including home births, since 1967. Ultrasound-based definition of gestational age has been registered with the MBRN since 1999, and we therefore chose from 1999 to 2018 as the study period.

Information on maternal health before and during pregnancy in the MBRN is based on documentation in primary healthcare (on standardised antenatal charts) and hospital medical records. Interventions and outcomes during labour and delivery are documented in the maternity units, and a standardised notification on maternal and newborn health is sent to the MBRN after a birth by the attending midwife.

In Norway, all women receive antenatal care (including routine ultrasound at second trimester) and delivery in public hospitals for free; less than 1% of women choose home birth. There are no private delivery departments in Norway, with all childbirths being managed in public hospitals. Care is provided in the delivery departments of the hospitals by midwives and obstetricians, and is free of charge regardless of the interventions performed. Care at neonatal units is also free of charge. Fetal monitoring with cardiotocography (CTG) solely or in combination with automatic ST-segment analyses of fetal ECG (STAN), fetal blood sampling (FBS) are used by indication. Low-risk labours are monitored with intermittent fetal auscultation. Partograph is used routinely in all births.

Study population

All births with defined Robson group, from 22+0 gestation weeks were included. The study population consisted of 1 153 789 births (live births and stillbirths) and 1 174 066 newborns during 1999–2018 (table 1).

Variable definitions

The Robson Ten-Group Classification of CS (hereafter 'Robson group') was used to assess the trends in CS rates during the study period. It is based on the few simple obstetrical parameters of parity, previous CS history, gestational age, labour onset, fetal presentation and number of fetuses:

Group 1: Nulliparous women with one fetus in cephalic presentation at term (≥37 weeks), with spontaneous labour onset.

Group 2: Nulliparous women with one fetus in cephalic presentation at term (≥37 weeks), with labour onset induction or planned CS.

Group 3 (≥37 weeks): Parous women with one fetus in cephalic presentation at term (≥37 weeks), with spontaneous labour onset.

Group 4 (≥37 weeks): Parous women with one fetus in cephalic presentation at term (≥37 weeks) without previous CS, with labour onset induction or planned CS.

Group 5: Parous women with at least one previous CS.

Group 6: Nulliparous women with one fetus in breech presentation, including preterm births.

Group 7: Parous women with one fetus in breech presentation, including preterm births and women with previous CS.

Group 8: All women with multifetal pregnancies and all parities, including women with previous CS and preterm births.

Group 9: All women with one fetus in transverse or oblique presentation, including women with previous CS.

Group 10: All women with one fetus in cephalic presentation, and <37 weeks of gestation.

Births without a defined Robson group were categorised into a separate group.

The annual CS rate of each Robson group was determined to observe the time trends. Furthermore, the 20-year period was split into 2-year epochs to reduce the year-to-year variation, especially in the smallest Robson groups.

Labour onset was defined as either spontaneous, induction or primary CS. Planned CS was defined as CS performed before labour onset and intrapartum CS was defined as the CS performed during labour.

Maternal age was categorised by the following groups: <25, 25–29, 30–34, 35–39 and ≥40 years. Maternal country of birth was categorised by world regions based on World Bank classification, which considers political, geographical, economic and cultural characteristics.

Europe was divided into countries based on the European Economic Association (EEA) guidelines, including Switzerland, and countries outside the EEA. Due to the small number of women born in Transcaucasia and Central Asia, they were merged with women born in non-EEA European countries. Women born in East Asia or Oceania were merged with those born in East Asia Pacific/Oceania. Women with unknown country of birth were categorised into a separate group (table 1).

Parity was defined as the number of previous live births and stillbirths.

Fetal presentations were classified as cephalic, breech, transverse or oblique.

Table 1 Characteristics of the study population according to time period (n=1 153 789)

	1999–2000 n=116 372	2017–2018 n=110 819	1999–2018 n=1 153 789
Maternal age in years, mean±±SE/median±SD	29.02±±0.015/ 29.00±5.00	30.46±±0.015/ 30.00±4.90	29.77±±0.005/ 30.00±5.13
Maternal age, years			
<25	18.5 (21 513)	10.9 (12 080)	15.8 (181 743)
25–29	35.9 (41 775)	32.6 (36 181)	32.5 (374 418)
30–34	31.7 (36 854)	35.9 (39 808)	33.5 (387 027)
35–39	12.0 (13 991)	16.8 (18 644)	15.3 (176 988)
≥40	1.9 (2239)	3.7 (4106)	2.9 (33 613)
Parity			
Nulliparous	40.1 (46 612)	42.2 (46 768)	41.7 (481 468)
Para ≥1	59.9 (69 760)	57.8 (64 051)	58.3 (672 321)
Labour induction	10.5 (12 176)	23.2 (25 714)	16.6 (191 874)
Maternal country of birth			
Norway	83.8 (97 507)	69.2 (76 632)	77.2 (890 233)
Europe, EEA*	4.5 (5263)	11.3 (12 552)	7.5 (86 719)
Europe, non-EEA/Transcaucasia/Central Asia†††	1.1 (1289)	2.8 (3056)	2.1 (24 008)
North America‡	0.6 (655)	0.4 (464)	0.4 (5108)
Latin America/Caribbean§	0.5 (552)	1.0 (1156)	0.9 (10 336)
Middle East/North Africa¶	1.4 (1574)	3.6 (3966)	2.4 (27 136)
Sub-Saharan Africa**	1.2 (1396)	4.8 (5290)	3.0 (34 244)
South Asia‡‡	1.9 (2239)	2.5 (2795)	2.2 (25 402)
East Asia, Pacific, Oceania§§¶¶	1.9 (2231)	3.5 (3871)	3.0 (34 970)
Unknown	3.2 (3666)	0.9 (1037)	1.4 (15 633)
Prepregnancy BMI, n=406 937			
≥25.0 kg/m^2	Missing	34.8 (33 890)	34.3 (139 736)
≥30.0 kg/m^2	Missing	10.9 (12 114)	12.1 (49 366)
Smoking early in pregnancy, n=986 322			
Daily	22.2 (22 448)	2.9 (2962)	11.7 (112 029)

Data are % (n) values, except where indicated otherwise.
*Europe, EEA: Sweden, Finland, Denmark, Iceland, Cyprus, Bulgaria, Estonia, Croatia, Latvia, Poland, Romania, Lithuania, Slovenia, Hungary, Slovakia, Czech Republic, Belgium, France, Greece, Ireland, Italy, Malta, The Netherlands, Liechtenstein, Luxembourg, Portugal, Spain, UK, Switzerland (not actually in the EEA), Germany and Austria.
†Europe, non-EEA: Greenland, Faroe Islands, Albania, Belarus, Moldova, Russia, Turkey, Ukraine, Bosnia-Herzegovina, Macedonia, Serbia, Montenegro, Kosovo, Andorra, Gibraltar, Monaco, San Marino, Vatican City, Guernsey, Jersey and Isle of Man.
‡North America: Canada, St. Pierre and Miquelon and USA.
§Latin American/Caribbean: US Virgin Islands, Barbados, Antigua and Barbuda, Belize, Bahamas, Bermuda, British Virgin Islands, Cayman Islands, Costa Rica, Cuba, Dominica, Dominican Republic, Grenada, Guadeloupe, Guatemala, Haiti, Honduras, Jamaica, Martinique, Mexico, Montserrat, Aruba, St. Martin, Bonaire, St. Eustatius, Saba, Anguilla, Curaçao, Nicaragua, Panama, El Salvador, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Trinidad and Tobago, Turks and Caicos Islands, Puerto Rico, St. Martin, Saint-Barthélemy, Argentina, Bolivia, Brazil, Guyana, Chile, Colombia, Ecuador, Falkland Islands, French Guiana, Paraguay, Peru, Suriname, Uruguay and Venezuela.
¶Middle East/North Africa: Algeria, Egypt, Djibouti, Libya, Morocco, Tunisia, Bahrain, United Arab Emirates, Iraq, Iran, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria and Yemen.
**Sub-Saharan Africa: Angola, Botswana, St. Helena, Burundi, Comoros, Benin, Equatorial Guinea, Côte d'Ivore, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Cameroon, Cape Verde, Kenya, Congo, Lesotho, Liberia, Madagascar, Malawi, Mali, Western Sahara, Mauritania, Mauritius, Namibia, Niger, Nigeria, Mozambique, Mayotte, Réunion, Zimbabwe, Rwanda, São Tomé and Príncipe, Senegal, Central African Republic, Seychelles, Sierra Leone, Somalia, South Sudan, Sudan, Swaziland, South Africa, Tanzania, Chad, Togo, Uganda, Zambia and Burkina Faso.
††Transcaucasia/Central Asia: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.
‡‡South Asia: British Indian Ocean Territory, Afghanistan, Bangladesh, Bhutan, Sri Lanka, India, Maldives, Nepal and Pakistan.
§§East Asia Pacific: Brunei, Myanmar, Philippines, Taiwan, Hong Kong, Indonesia, Japan, Cambodia, China, North Korea, South Korea, Laos, Macao, Malaysia, Mongolia, Timor Leste, Singapore, Thailand, Vietnam, Solomon Islands, Fiji, Vanuatu, Tonga, Kiribati, Tuvalu, Nauru, Federated States of Micronesia, Papua New Guinea, Samoa, Marshall Islands and Palau.
¶¶Oceania: American Samoa, Australia, Christmas Island, Cocos (Keeling) Islands, Cook Islands, French Polynesia, Guam, US Minor Outlying Islands, New Zealand, Niue, Norfolk Island, Pitcairn Islands, Tokelau, Wallis and Futuna Islands, New Caledonia and Northern Mariana Islands.
BMI, body mass index; EEA, European Economic Association.

Low Apgar scores at 5 min of age, and the prevalence rates of intrapartum, perinatal and neonatal mortality were used to evaluate neonatal outcomes.

Intrapartum fetal mortality was defined as death from 22+0 gestation weeks, which occurred during labour or delivery. Perinatal mortality was defined as fetal death after 22+0 gestation weeks, during pregnancy, labour or during the first week of life. Neonatal mortality was defined as a death of a liveborn child during the first 4 weeks of life. Low Apgar scores were analysed with two criteria: <4 or <7 at 5 min of age, among liveborn infants.

Missing data

Due to missing information on gestational age or delivery mode, 0.5% (5943/1 153 789) of the births were not classified into Robson groups and so were analysed in a separate group. The maternal country of birth was unknown in 1.4% of the births.

Statistical analysis

Continuous data were categorised. Prevalence rates with 95% CIs were calculated to identify significant differences in CS rates between the time periods as well as in fetal and newborn outcomes. X^2 test was used to calculate probability values, with p<0.05 defined as a significant difference, to illustrate the changes in overall CS rate in the study period. IBM SPSS Statistics (V.26, IBM Corporation, Armonk, New York, USA) was used to perform all analyses.

Patient and public involvement

No patient involved.

RESULTS

The first (1999–2000) and last (2017–2018) time periods are presented separately to illustrate the changes in maternal characteristics (table 1). Following changes in maternal characteristics were observed: mean maternal age increased from 29.02 to 30.46 years, the proportion of women aged ≥40 years increased from 1.9% to 3.7% and the prevalence of women with advanced age (≥35 years) when giving birth increased from 13.9% to 20.7%. The proportion of nulliparous women increased from 40.1% to 42.2%, and that of immigrant women approximately doubled (from 16.2% to 30.8%) during the study period, as did the rate of labour induction (from 10.5% to 23.2%) (table 1). The MBRN started to collect maternal height and prepregnancy weight data in 2007; the prevalence rates of overweight and obesity are therefore only presented for the last epoch (2017–2018) and no time trend is available. Overweight (body mass index (BMI) ≥25 kg/m^2) was observed in 34.8% of the women and 10.9% of the women were obese (BMI ≥30 kg/m^2) (table 1).

The overall CS rate increased from 12.9% in 1999 to its highest value of 16.7% (9903/59 559) in 2008 (p<0.001). After 2008, the CS rate reduced to 15.8% in 2018 (p<0.001) (figure 1). The annual changes in Robson groups are illustrated in figures 2–6. CS rates in most Robson groups were reduced from 2008 to 2018, the largest proportional reductions observed in Robson groups 2 and 4.

Table 2 lists the CS rates (with 95% CIs) in the Robson groups for three 2-year epochs, the first (1999–2000), middle (2007–2008) and last (2017–2018). The entire study period with 10 epochs presented in online supplemental table 1. From 1999–2000 to 2007–2008, the CS rates increased in all Robson groups except group 3, for which the CS rate varied between 1.5% and 2.0% during the entire study period. Further changes in CS rates were observed from 2007–2008 to 2017–2018. In Robson group 2 the planned CS rate decreased by 52% from 9.6% in 2007–2008 to 4.6% in 2017–2018, and the intrapartum CS

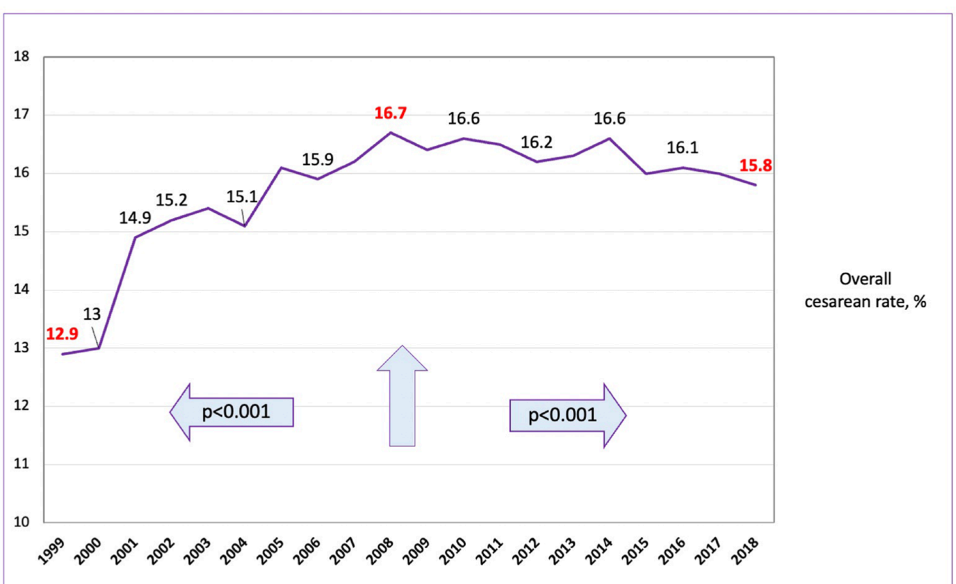

Figure 1 Overall caesarean rates by year, in %.

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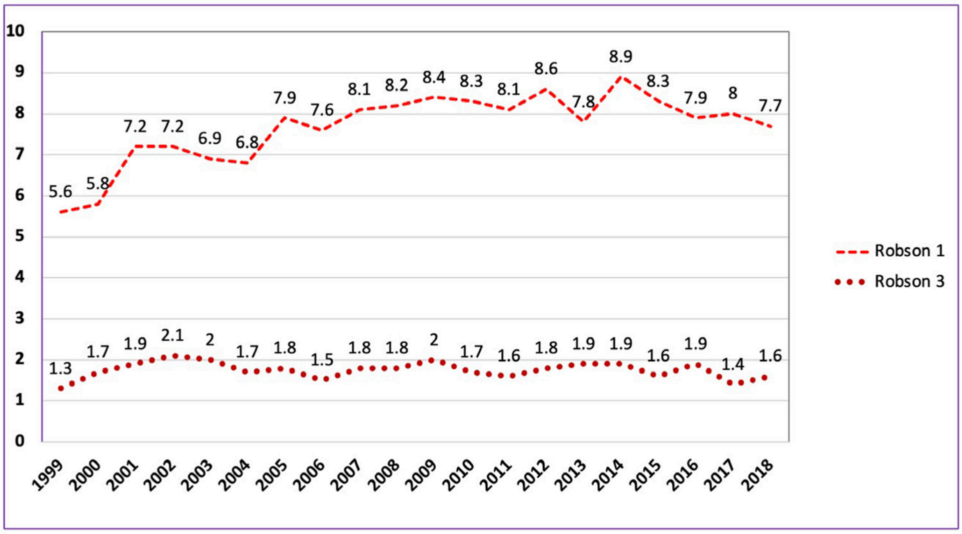

Figure 2 Intrapartum caesarean rates in Robson groups 1 and 3 by year, in %.

rate decreased by 16%, from 26.6% to 22.3% (table 2). In Robson group 4 the planned CS rate decreased by 54% (from 16.1% to 7.4%) and the intrapartum CS rate decreased by 33%, from 7.8% to 5.2% (table 2). In Robson group 5 the planned CS rate decreased by 11.6% from 31.8% to 28.1%, and the intrapartum CS rate increased by 17.3% to 19.6%, resulting in an unchanged total CS rate among women with previous CS (49.1% vs 47.7%) (table 2). In Robson group 6 (nulliparous women with breech presentation) a 30% increase in CS rate was observed from the first (59%) to the second (76.9%) epoch, and the CS rate remained over 70% in the rest of the study period. A similar trend was observed in Robson group 7, with a 27% increase from 51.1% in 1999–2000 to 64.9% in 2017–2018 and the rate remained higher than 60% during the rest of the study period (table 2). In Robson groups 8 and 10 the CS rates slightly decreased by 4–8% while in groups 1 and 3 they were unchanged between 2007–2008 and 2017–2018 (table 2). In Robson group 9 the CS rates exceeded 95% over the entire study period (table 2). The CS rates varied between 42.9% and 62.2% in the group that was not defined by the Robson classification (table 2).

Intrapartum fetal mortality decreased from 0.51 per 1000 (‰) in 1999–2000 to 0.40‰ in 2007–2008 and further to 0.14‰ in 2017–2018 (table 3). The decrease from the first to the last epoch was 72%. Perinatal mortality decreased by 37% from 7.00‰ in 1999–2000 to 4.38‰ in 2017–2018, and a significant decrease was observed also from 2007–2008 to 2017–2018, from 5.83‰ to 4.38‰

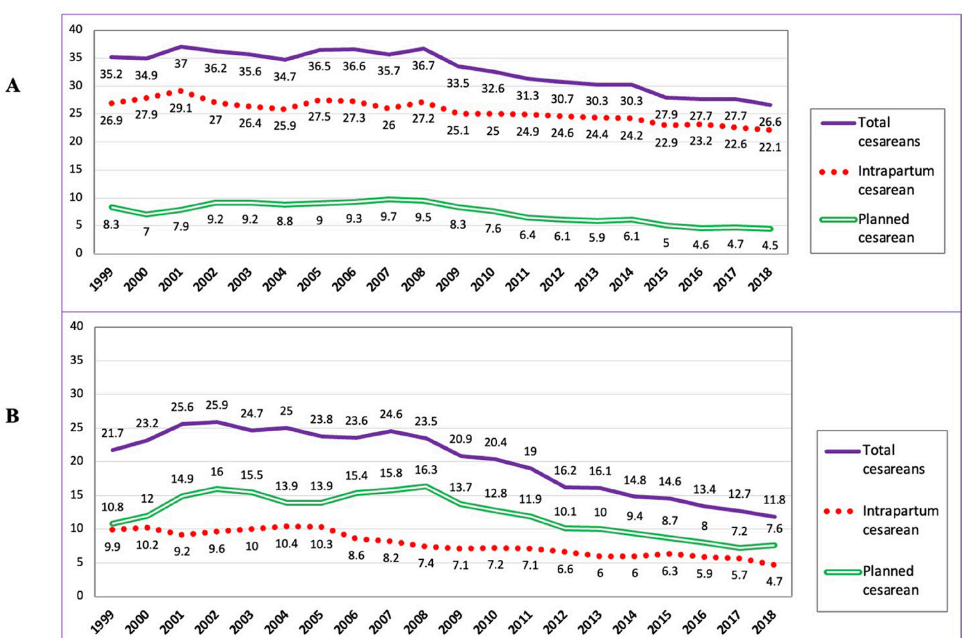

Figure 3 Caesarean rates in Robson groups 2 (A) and 4 (B) by year, in %.

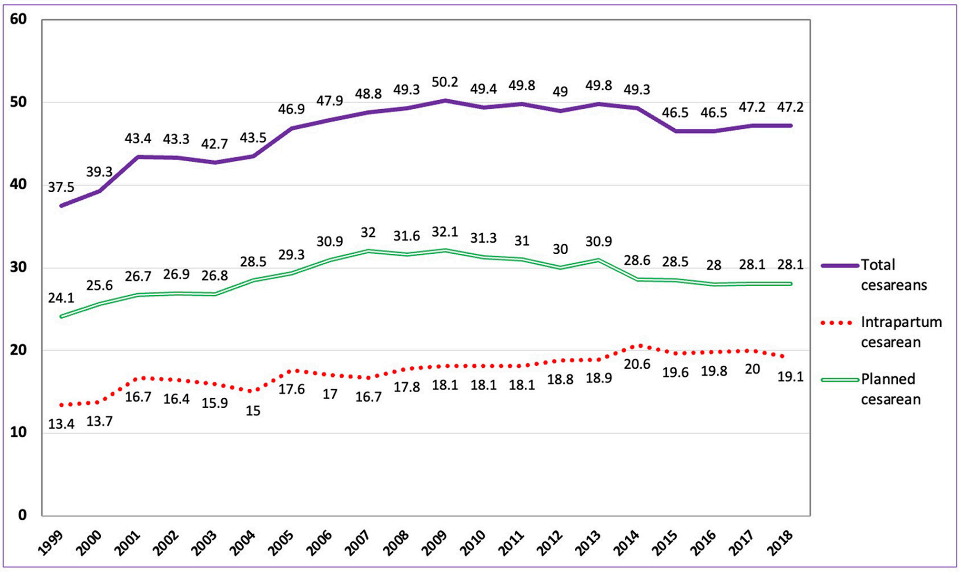

Figure 4 Caesarean rates in Robson group 5 by year, in %.

(table 3). Neonatal mortality decreased by 36% from 2.52‰ in the first period to 1.58‰ in the last period. The change from 2007–2008 to 2017–2018 was not significant (table 3). The proportion of liveborn infants with low Apgar scores (<4) at 5 min of age increased from 2.54‰ in 1999–2000 to 4.00% in 2007–2008 (when the CS rate peaked), and then decreased to 2.56‰ in 2017–2018 (table 3). The proportion of liveborn infants with Apgar scores <7 at 5 min age increased from 12.10‰ in 1999–2000 to 13.99‰ in 2007–2008 and then remained similar in the last period (14.25‰) (table 3).

Table 4 illustrates the distribution of Robson groups in the study population in the first, middle and last 2-year epochs. The notable increase in labour inductions during the study period is reflected in the reduced proportion of women in Robson groups 1 and 3 and increased number of births in groups 2 and 4.

DISCUSSION

A notable increase was observed in overall CS rate immediately after 1999, especially in Robson groups 6 and 7, which represent the delivery of infants in the breech presentation. This increase was likely influenced by the Term Breech Trial (TBT), which concluded that planned CS was safer than vaginal delivery for infants in breech presentation.[8] CS rates increased also in other Robson groups, which may indicate a general liberalisation of

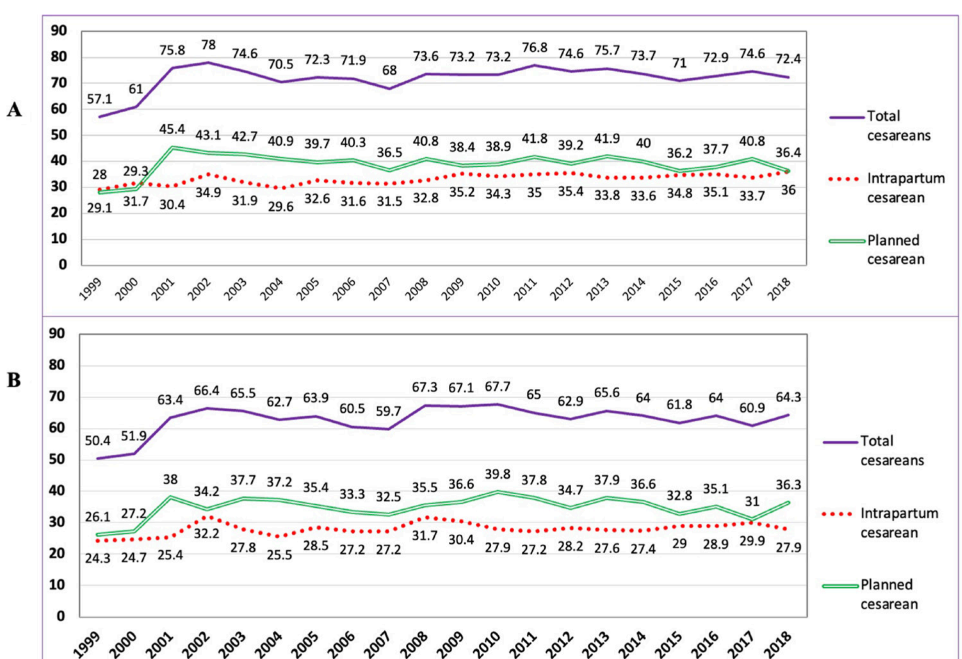

Figure 5 Caesarean rates in Robson groups 6 (A) and 7 (B) by year, in %.

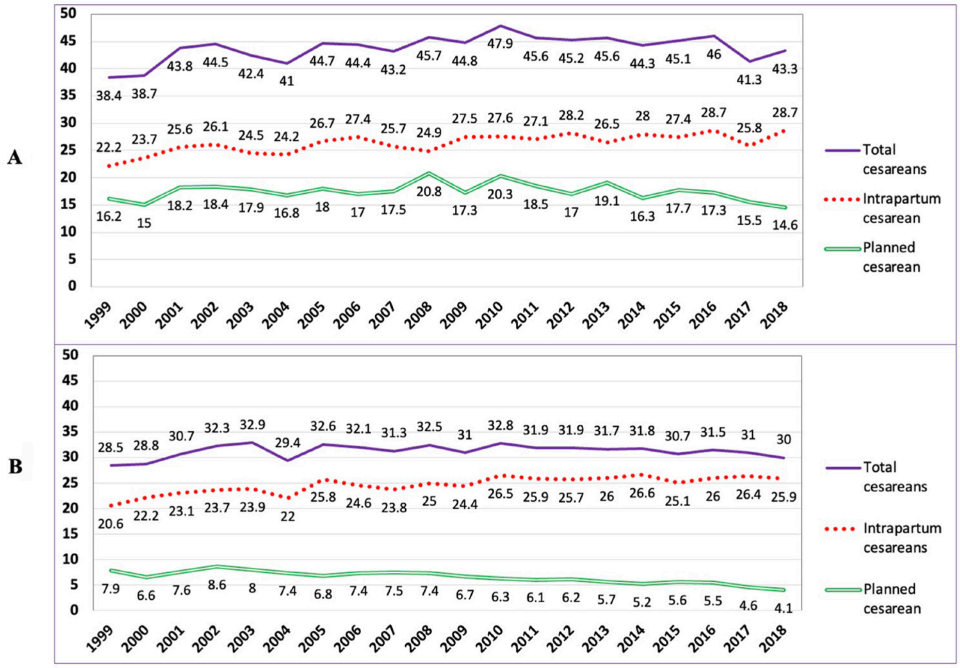

Figure 6 Caesarean rates in Robson groups 8 (A) and 10 (B) by year, in %.

CS use in other indications than breech presentation. A similar trend has been observed in many other countries.[9 10]

After the period of increasing CS rates in Norway up to 2008, a significant reduction in overall CS rate was observed, mostly caused by the reduced use of both planned and intrapartum CS in Robson groups 2 and 4. Moderate but significant reductions in CS rates among multifetal (from 44.5% to 42.3%) and preterm (from 31.9% to 30.5%) births were also observed. Only a few previous studies have found successful CS rate reductions, but those studies did not analyse perinatal or neonatal outcomes.[11–13]

While there was a moderate absolute reduction in the overall CS rate, it is important to emphasise that this was observed in an era of large global CS rate increases. Furthermore, the reduced CS rate was observed in a period of significantly increasing maternal age, increasing proportion of immigrant women in Norway and when labour induction use was doubled. Also, a notable proportion of women were overweight, with every third mother having BMI ≥25 kg/m^2.

CS is a life-saving procedure when it is indicated, but it also has harmful effects on the mother and child and its use should therefore be restricted to when it is medically recommended. The prevalence rates of maternal mortality and morbidity are higher after CS than after vaginal birth.[14 15] Previous CS is associated with increased risks of uterine rupture, abnormal placentation, ectopic pregnancy, stillbirth and preterm birth in subsequent pregnancies.[14 15] Infants born via CS have different hormonal and bacterial exposures than those delivered vaginally, and this can alter their immune system development.[16] Children born via CS have increased risks of asthma, type 1 diabetes, allergies[17–19] and obesity,[20] and reduced intestinal gut microbiome diversity.[21] Recent studies have indicated that prelabour CS may be associated with adverse child cognitive scores[22] and school performance.[23] Due to these potentially harmful health effects, CS overuse has become a global patient safety issue.[6]

The CS rates increased during the first five epochs of the present study and decreased in the other epochs. Intrapartum, perinatal and neonatal mortality rates decreased throughout the study period. However, the prevalence of low Apgar scores was highest in the period with the highest CS rate (2007–2008). It is notable that even though important outcomes such as intrapartum fetal death and perinatal and neonatal mortality decreased in Norway, the prevalence of low Apgar scores did not; we can only speculate about the underlying causes. Apgar score is a subjective evaluation method for newborns, and should not be used alone as a measure of fetal asphyxia.[24] We cannot rule out the possibility that the use of Apgar score had changed during the study period. Parallel with an increasing prevalence of low Apgar scores, a Norwegian study found that cerebral palsy rates, especially of quadriplegia and dyskinetic cerebral palsy (considered to be the result of hypoxic ischaemic encephalopathic injuries at birth), decreased significantly from 1999 to 2009.[25] The authors consider that improvements in obstetrical and neonatal care have had a major impact on reducing cerebral palsy prevalence.

We believe that the limited caesarean use in Norway is a combination of many factors and actions over time. Two national quality-improvement projects were conducted in Norway, which focused on the correct use of CS and increasing the awareness of restricting CS use to medically

Table 2 Caesarean section (CS) rates according to Robson groups for 2-year epochs. Top row showing the number of births in the time period. Data are the percentage prevalence (95% CI) values and the number of caesareans for each group. Left column showing the number of births in each Robson group for the entire study period 1999–2018

	1999–2000 n=116 372	2007–2008 n=117 121	2017–2018 n=110 819
Robson group 1 Intrapartum CS n=331 319	5.7 (5.5 to 6.0) n=1953	8.1 (7.8 to 8.4) n=2823	8.2 (7.8 to 8.5) n=2414
Robson group 2 Planned CS n=89 835	7.6 (6.9 to 8.3) n=430	9.6 (9.0 to 10.2) n=840	4.6 (4.2 to 5.0) n=536
Robson group 2 Intrapartum CS n=89 835	27.4 (26.2 to 28.6) n=1545	26.6 (25.7 to 27.5) n=2329	22.3 (21.6 to 23.7) n=2606
Robson group 3 Intrapartum CS n=433 275	1.3 (1.2 to 1.4) n=657	1.8 (1.7 to 1.9) n=791	1.7 (1.5 to 1.8) n=632
Robson group 4 Planned CS n=87 433	11.4 (10.5 to 12.3) n=625	16.1 (15.3 to 16.8) n=1371	7.4 (6.9 to 7.9) n=811
Robson group 4 Intrapartum CS n=87 433	10.1 (9.3 to 10.9) n=551	7.8 (7.2 to 8.3) n=685	5.2 (4.8 to 5.6) n=572
Robson group 5 Planned CS n=90 353	24.9 (23.9 to 25.9) n=1911	31.8 (30.8 to 32.7) n=2936	28.1 (27.2 to 28.9) n=2723
Robson group 5 Intrapartum CS n=90 353	13.5 (12.8 to 14.3) n=1039	17.3 (16.4 to 18.0) n=1593	19.6 (18.8 to 20.4) n=1903
Robson group 6 Breech, nulliparous n=23 040	59.0 (57.0 to 61.0) n=1346	70.8 (68.9 to 72.6) n=1654	73.5 (71.7 to 75.3) n=1737
Robson group 7 Breech, parous n=18 241	51.1 (49.0 to 53.3) n=1069	63.4 (61.2 to 65.6) n=1147	62.5 (60.3 to 64.8) n=1113
Robson group 8 Multifetal n=20 040	38.6 (36.4 to 40.6) n=809	44.5 (42.3 to 46.6) n=936	42.3 (39.9 to 44.6) n=726
Robson group 9 Transverse/oblique n=3442	95.6 (93.3 to 97.9) n=305	92.2 (89.5 to 94.9) n=356	100 (=100 to 100) n=356
Robson group 10 Preterm n=50 868	28.7 (27.5 to 29.9) n=1529	31.9 (30.7 to 33.1) n=1744	30.5 (29.2 to 31.9) n=1327
No Robson group n=5943	52.2 (50.1 to 54.4) n=1086	42.9 (35.3 to 50.6) n=70	62.2 (55.8 to 68.6) n=140

indicated situations. The first project was conducted in 1998–1999,[26 27] and focused on distinguishing normal physiology and high-risk labour, and restricting the use of interventions. No reduction of CS use was achieved after this. The TBT was reported on shortly after this project in 2001,[8] and it may have influenced the general liberalisation of CS use among Norwegian obstetricians. A new quality-improvement project was conducted during 2014–2016 using the 'Breakthrough Series Collaborative' method.[28] Management of labour dystocia, oxytocin use, fetal monitoring, diagnostics and management of fetal asphyxia, labour induction and the continuous presence of a midwife during active labour were the priority topics, and each maternity unit chose what to focus on. The CS rate gradually decreased from 2008, and we cannot affirm if the quality-improvement projects directly affected the CS rates in Norway.

Several quality-improvement actions have been established to continuously improve obstetrical care in Norway. National guidelines in obstetrical care have been regularly updated by the Norwegian Society of Gynecology and Obstetrics since 1995. A national reference group for fetal monitoring was established in 2004, with both midwives and doctors as members, and annual meetings are organised to educate midwives and doctors on interpreting advanced fetal monitoring scans (CTG, FBS or

Table 3 Fetal and newborn outcomes during three study periods (including multifetal births). Data are the prevalence rates per 1000 (‰) with 95% CIs

Mortality time	1999–2000	2007–2008	2017–2018
Live births and stillbirths	n=118 511	n=119 193	n=117 563
Intrapartum	0.51 (0.38 to 0.63) n=60	0.40 (0.29 to 0.52) n=48	0.14 (0.07 to 0.21) n=16
Perinatal	7.00 (6.53 to 7.48) n=830	5.83 (5.40 to 6.26) n=695	4.38 (4.00 to 4.77) n=493
Neonatal	2.52 (2.24 to 2.81) n=299	1.89 (1.64 to 2.13) n=225	1.58 (1.35 to 1.81) n=178
Apgar score at 5 min (calculated from live births)	**1999–2000**	**2007–2008**	**2017–2018**
	n=117 709	n=118 518	n=112 459
<4	2.54 (2.25 to 2.83) n=298	4.00 (3.64 to 4.36) n=474	2.56 (2.26 to 2.86) n=287
<7	12.10 (11.47 to 12.72) n=1419	13.99 (13.32 to 14.66) n=1658	14.25 (13.56 to 14.95) n=1598

STAN). Perinatal audits exploring stillbirths and perinatal deaths are continuously carried out to educate and support clinicians in making objectively justified decisions. Furthermore, the Norwegian health authorities require all maternity units to organise local interprofessional education in fetal monitoring, emergency obstetrics and neonatal resuscitation. Patient injury compensation is based on no-fault rules in Norway, and compensation claims are handled by focusing on learning from the cases rather than the blame or negligence of the medical personnel.

The above-described continuous national, multifactorial and multidisciplinary collaboration on obstetrical care quality with focus on normal physiological labour and delivery and restricting medical intervention use may have affected the attitudes among Norwegian midwives and obstetricians, resulting in restricting or even reducing the use of CS over time.

Evolution in neonatal medicine has played a substantial role in improving the health of newborns; for example, hypothermia as a treatment for hypoxic infants was implemented in Norway in 2008.

Table 4 Distribution of Robson groups in the study population in the 2-year epochs. Top row showing the number of births in the time period

	1999–2000 n=116 372	2007–2008 n=117 121	2017–2018 n=110 819
Robson group 1	29.4 (34 168)	29.7 (34 727)	26.7 (29 577)
Robson group 2	4.8 (5638)	7.5 (8749)	10.5 (11 678)
Robson group 3	42.3 (49 214)	37.2 (43 609)	34.4 (38 096)
Robson group 4	4.7 (5476)	7.3 (8 536)	9.9 (10,980)
Robson group 5	6.6 (7678)	7.9 (9233)	9.9 (9698)
Robson group 6	2.0 (2292)	2.0 (2337)	2.1 (2363)
Robson group 7	1.8 (2090)	1.5 (1809)	1.6 (1780)
Robson group 8	1.8 (2098)	1.8 (2105)	1.6 (1718)
Robson group 9	0.3 (319)	0.3 (386)	0.3 (356)
Robson group 10	4.6 (5330)	4.7 (5467)	3.9 (4348)
Missing information on Robson group	1.8 (2079)	0.1 (73)	0.2 (225)

Strengths

The inclusion of a large data sample enabled us to assess trends over time. The MBRN is considered a reliable and suitable data source for research.[29] The history of data collection in the MBRN is long, which started in 1967, and a large amount of work and impact have been used to continuous control the quality of the data. The proportion of missing values was therefore low in this study.

Limitations

Data on indications for CS or labour are not collected by the MBRN and were therefore not available for analysis in this study. We therefore were not able to differentiate between CS by maternal request or the most common indications of CS, labour dystocia and fetal distress, or assess possible changes in them over time.

CONCLUSION

After the period of increasing CS rates during 1999–2008, a significant decrease was observed in Norway from 2008 to 2018 along with a reduction of fetal intrapartum, perinatal and neonatal mortality rates. Norwegian obstetricians and midwives have maintained low CS rates (<17%), in contrast with most other countries struggling with notable increases.[30] This is probably due to multiple continuous interprofessional quality-improvement actions on correct CS use in Norway, restricting this procedure to mostly medical indications. Our findings indicate that restricting CS use is a safe option for perinatal health.

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Contributors KL, ADP and BMY contributed to the planning and design of the study, interpretation of the data and critical revision of the manuscript. KL drafted the manuscript and performed the analyses. Guarantor, KL.

Funding The Norwegian SIDS and Stillbirth Society provided financial support for the retrieval of data from the registries (grant number 554.04/14).

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The study was approved by the Regional Committee for Medical Research Ethics in South East Norway in 2015 (approval number 2015/681) and the Institutional Personal Data Officer at Oslo University Hospital.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement The data describing the findings of this study are available for researchers from the Medical Birth Registry of Norway. Restrictions apply to the availability of these data, which were used under license solely for the authors. Detailed data for this study cannot be shared, according to the Norwegian health research legislation.

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