Mode of first delivery and later fertility and fecundity: Evidence from Thirteen Demographic and Health Surveys

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Abstract

Around the world, more than 20% of births are by cesarean delivery, with large increases over the past decade. While previous studies have shown associations between cesarean delivery and subsequent infertility and infecundity in high-income countries, previous research on this topic in low- and middle-income countries has not found the same associations. However given the recent increases in cesareans, it is important to investigate these a link between cesarean delivery and infertility and infecundity with more current data. This study used data from the pregnancy history included in the eighth round of the Demographic and Health Survey Program to investigate this question. We created variables on mode of first birth, subsequent pregnancies and births, and other covariates, from household survey data in thirteen countries between 2021 and 2024 and used a robust multivariable Poisson regression model to estimate the association between mode of first birth and subsequent pregnancy and birth, controlling for time since first birth. Sensitivity analyses were conducted using survival analysis.

Across the thirteen countries, sample size of women who had had a first birth reported in the three-year pregnancy history ranged from 697 women in Lesotho to 3109 in Kenya. The proportion of women who had their first child by cesarean section ranged from 7.2% in Mozambique to 50.7% in Bangladesh, while the proportion of women with a second birth reported ranged from 4.6% in Lesotho, to 24.7% in Jordan. Cesarean delivery was positively associated with no subsequent pregnancies or births in four countries - Cambodia, Cote d'Ivoire, Ghana, and Senegal – although the sensitivity analyses showed the instability of these findings.

Our analysis shows that in certain contexts there is an association between cesarean delivery and later fertility and fecundity. Future research should include longer periods of follow-up to capture more pregnancies and births after first birth.

Introduction

A cesarean section (CS) can be lifesaving interventions but can have potential risk to pregnant women and their babies. Previous studies in the United States and other high-income countries have shown that women who delivered their first child by CS have lower rates of conception and live birth compared to women who delivered their first child vaginally (Kristen H. Kjerulff et al. 2020; K. H. Kjerulff et al. 2013; Mollison et al. 2005; Porter et al. 2003). In low- and middle-income country countries (LMICs), the only study that has examined this question was a 2006 study looking at CS and subsequent births in sub-Saharan Africa (Collin, Marshall, and Filippi 2006). While this study did not find any significant association when looking at individual country data, there was a significant negative association when the data from the 22 countries were pooled.

Nearly twenty years after this initial study, CS rates have dramatically increased in most countries around the world, and the largest increases have been seen in the less developed countries (22.6% increase) compared to the least developed countries (8.6% increase) (Ana Pilar Betran et al. 2021). Projections suggest that CS rates will near 30% by 2030. With these increases, it is important to understand the longer-term fertility implications of CS across country contexts.

In addition, the high-income country studies on this question have shown negative associations between CS first birth and not only subsequent live birth but subsequent pregnancy as well. The eighth round of the Demographic and Health Survey (DHS) Program changed from a birth-based to a pregnancy-based reproductive history, which allows us to explore both outcomes of later fecundity (defined here as having a subsequent pregnancy) as well as later fertility (defined here as having a subsequent birth). Therefore, in this analysis, we assessed whether or not there are differences in subsequent birth and pregnancy among women who delivered their first birth by CS compared to those who delivered vaginally.

Data and methods

Data

We used data from thirteen recent surveys from the 8th round of The Demographic and Health Survey (DHS) Program. The countries and years are listed in Table 1. In the 8th round of DHS, the survey included a pregnancy history instead of the previous birth history. All women of reproductive age in selected households were interviewed[1], and they were asked to list all of their pregnancies and their outcomes (live birth, stillbirth, miscarriage). For all pregnancies in the 35 months before the interview, women were asked detailed questions about medical care, including the mode of delivery for the births.

Methods

Measures

Using recent DHS survey data from the thirteen countries (see Table 1), we merged pregnancy history information with individual women's information. The key independent variable of interest, mode of first birth, was assessed using the date of first birth and mode of delivery variables. The outcome variables of subsequent pregnancies and births were identified from the pregnancy history. A woman was identified as having a subsequent pregnancy if she reported having a pregnancy after the index birth that ended at any time before the interview. She was identified as having a birth if she reported having a birth after the index birth any time before the date of the interview. Exposure time was assessed from date of first birth to the date of end of the subsequent pregnancy or date of live birth or the date of interview for women who did not have a subsequent pregnancy or live birth.

We created variables for the other maternal and neonatal factors which have been associated with fertility and fecundity in past research:

- Maternal factors
    - *age at first birth*: younger than 30 or 30 years and older
    - *residence*: urban or rural
    - *wealth quintile*: poorest, poorer, middle, richer, richest

[1] Except for Jordan and Bangladesh, were only ever-married women of reproductive age were interviewed.

    - *highest level of education completed*: no education, completed primary, higher than primary school
    - *ever married*: any previous union or no previous union
    - *wants another child*: wants another child at any time in the future or is undecided about wanting another child
    - *no contraceptive use*: did not use contraception at any time since the first birth
- Neonatal factors (first birth)
    - *sex of child at birth*: male or female
    - *size of child at birth*: small, average, or large

Analysis

This analysis excluded women who had not had a first birth in the 3-year period of the pregnancy history, as well as women who did not have a response for "mode of birth" for their first birth.

The multivariable analysis included the previously described variables which had been previously shown to be associated with later fertility and fecundity. Before conducting the multivariable analysis, we examined the variance inflation factor (VIF) for all covariates. All VIFs were within acceptable range and therefore all covariates were kept in the model.

In order to be able to account for time since first birth and following guidance for relative measures of association using binary outcomes (Gallis and Turner 2019; GY Zou and Donner 2013), we used a robust Poisson regression model to estimate the association of mode of first birth with subsequent birth and pregnancy, first with a bivariate model, and then a multivariable model controlling for other important factors. Following Zou (Guangyong Zou 2004), we interpreted the incidence rate ratio as a risk ratio. Both models controlled for exposure time. All statistical tests were run in Stata 18 and adjusted for the complex survey design and applied survey weights. Statistical significance was set at $p<0.05$.

We also ran sensitivity analyses using multivariable survival analysis using the same covariates due to the large amount of right censoring in the data. We initially used Cox Proportional Hazards models, but after assessing the proportional hazard assumption using Schoenfeld residuals, we selected an accelerated failure time (AFT) model with a Weibull distribution.

Results

In the thirteen surveys included in the analysis, the average period of follow-up from the date of first birth to the end of the subsequent pregnancy or the date of interview if no subsequent pregnancy/birth ranged from 18.9 months in Jordan to 23.1 months in Mozambique. The proportion of first births that were delivered by Cesarean ranged from 7.2% in Mozambique to 50.7% in Bangladesh, as shown in Table 1.

Table 1: Average period of follow-up and mode of first birth by country

Country	Year	Average period of follow-up in months (after first birth)	N	First birth			
				Vaginal (%)	95% CI	Caesarean (%)	95% CI
Bangladesh	2022	20.8	2070	49.4	[46.7, 52.1]	50.7	[48.0, 53.4]
Burkina Faso	2021	22.7	1507	92.5	[90.9, 93.8]	7.5	[6.2, 9.1]
Cambodia	2021-22	21.9	1658	80.1	[77.7, 82.2]	19.9	[17.8, 22.3]
Cote d'Ivoire	2021	23.0	1436	88.1	[85.5, 90.2]	12.0	[9.8, 14.5]
Ghana	2022	22.4	1514	77.9	[75.0, 80.5]	22.1	[19.5, 25.0]
Jordan	2023	18.9	856	56.4	[52.1, 60.7]	43.6	[39.3, 47.9]
Kenya	2022	20.8	3157	80.5	[77.7, 83.0]	19.5	[17.0, 22.2]
Lesotho	2023-24	22.6	635	75.3	[71.2, 79.1]	24.7	[20.9, 29.0]
Mozambique	2022-23	23.1	1431	92.8	[91.3, 94.0]	7.2	[6.0, 8.7]
Nepal	2022	21.2	1312	78.2	[75.3, 80.8]	21.8	[19.2, 24.7]
Philippines	2022	20.3	1481	77.2	[73.9, 80.2]	22.8	[19.8, 26.1]
Senegal	2023	22.2	1512	84.0	[81.6, 86.2]	16.0	[13.8, 18.4]
Tanzania	2022	21.7	1467	83.9	[81.0, 86.4]	16.1	[13.6, 19.0]

Table 2 shows the proportion of women who had a subsequent pregnancy or birth during the period covered by the pregnancy history. The country with the smallest proportion of both

pregnancies (5.0%) and births (4.6%) was Lesotho, while the country with the largest proportion of both pregnancies (27.8%) and births (24.7%) was Jordan.

Table 2: Proportion of women with a subsequent pregnancy or birth in the period of the pregnancy history.

Country	% of women with a:			
	subsequent pregnancy		subsequent birth	
	%	95% CI	%	95% CI
Bangladesh	7.6	[6.4, 9.0]	5.6	[4.6, 6.9]
Burkina Faso	8.6	[7.1, 10.4]	7.9	[6.5, 9.7]
Cambodia	13.3	[11.5, 15.5]	8.4	[6.8, 10.2]
Cote d'Ivoire	10.0	[8.1, 12.3]	7.9	[6.3, 9.8]
Ghana	11.0	[9.1, 13.1]	6.9	[5.5, 8.6]
Jordan	27.8	[23.7, 32.2]	24.7	[20.9, 29.0]
Kenya	10.8	[9.5, 12.3]	9.6	[8.4, 11.0]
Lesotho	5.0	[3.1, 8.1]	4.6	[2.7, 7.6]
Mozambique	10.6	[8.6, 13.0]	9.5	[[7.6, 11.9]
Nepal	12.8	[10.7, 15.2]	8.7	[7.0, 10.9]
Philippines	9.0	[7.3, 11.1]	7.9	[6.3, 9.9]
Senegal	10.3	[8.5, 12.4]	8.8	[7.1, 10.9]
Tanzania	12.8	[10.7, 15.2]	11.8	[9.8, 14.1]

In most countries, there were differences in subsequent pregnancy and/or birth by woman's highest level of completed schooling, marital status, and desire for another child (See Table 3). In ten countries women with higher levels of completed schooling were more likely to have a subsequent pregnancy and/or birth compared to women with lower levels of completed schooling. In eight countries women who reported wanting another child were less likely to have had subsequent pregnancy and/or birth compared to women who reported not wanting another child. In seven of the twelve countries with available marital status data, women who had ever been in union were more likely to have a subsequent pregnancy or birth. There were few consistent differences in the other covariates across the countries in the sample.

Table 3. Maternal and Child Characteristics and Association with Subsequent Pregnancy and Birth

		Bangladesh		Burkina Faso		Cambodia		Cote d'Ivoire		Ghana		Kenya		Jordan		Lesotho		Mozambique		Nepal		Philippines		Senegal		Tanzania	
		Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)	Pregnancy (%)	Birth (%)
Overall		7.6	5.6	8.6	7.9	13.3	8.4	10	7.9	11	6.9	10.8	9.6	27.8	24.7	5.0	4.6	10.6	9.5	12.8	8.7	9.0	7.9	10.3	8.8	12.8	11.8
Mode of first birth	**Vaginal**	**9.8**	**7.0**	**9.2**	**8.6**	**14.6**	**9.3**	10.8	8.6	11.6	7.5	11.0	9.8	28.9	27.3	5.6	5.0	**11.2**	**10.0**	**15.2**	**10.7**	**10.3**	**9.3**	**11.3**	**9.8**	13.2	12.2
	Cesarean Section	**5.4**	**4.3**	**1.8**	**0.4**	**8.3**	**4.6**	5.0	3.9	8.9	4.8	9.9	8.9	26.3	21.5	3.3	3.3	**3.0**	**3.0**	**4.2**	**1.8**	**4.8**	**3.1**	**5.3**	**3.9**	10.7	9.8
Age at first birth	Less than 30 years of age	7.7	5.7	8.5	7.8	13.4	8.0	9.9	8.0	10.8	6.8	**10.0**	**9.0**	27.4	24.4	5.1	4.6	10.4	9.3	13	8.9	9.1	8.0	**10.8**	**9.3**	12.8	11.7
	30+ years of age	4.0	4.0	11.7	11.7	12.6	11.6	10.4	7.9	13.4	7.9	**32**	**26.3**	29.6	26.6	3.7	3.7	22.7	22.7	8.6	6.2	8.7	7.3	**3.8**	**2.8**	13.6	13.6
Place of residence	Urban	7.8	5.9	6.5	**5.5**	14.8	8.3	8.6	6.5	11.7	6.1	10.8	9.2	28.9	**25.9**	7.0	5.8	**6.5**	**5.4**	12.4	7.9	8.1	7.0	**7.4**	**5.5**	9.5	9.0
	Rural	7.5	5.5	9.8	**9.3**	12.3	8.4	12	9.9	10.2	7.8	10.8	10	19.2	**15.4**	3.8	3.8	**12.5**	**11.5**	13.7	10.6	10.0	8.9	**12.8**	**11.6**	14.6	13.3
Wealth quintile	Poorest	**10.4**	6.9	11	10.7	13.9	9.8	11.7	10.3	9.9	8.6	**15.5**	**14.5**	**40.5**	**37.2**	9.2	9.2	12.3	**12.3**	13.2	11.6	13.2	11.8	12.6	11.5	15.4	13.9
	Poorer	**9.3**	7.2	9.4	8.7	11.6	8.6	14.5	9.4	13.0	8.0	**10.9**	**9.4**	**23.8**	**20.2**	2.0	2.0	10.9	**9.8**	13.6	9.8	8.9	8.2	10.2	9.4	16.5	15.5
	Middle	**6.8**	5.2	5.5	5.5	12.1	5.6	9.0	7.0	11.7	6.0	**12.6**	**11.8**	**22.5**	**18.9**	4.6	4.2	14.5	**13.8**	15.2	8.4	9.2	6.9	8.7	6.7	11.8	11.1
	Richer	**8.1**	6.1	10.7	9.5	13.3	7.7	8.6	7.6	8.5	5.5	**9.3**	**8.6**	**20.6**	**18.1**	6.5	4.9	8.4	**6.3**	8.8	7.1	8.9	7.6	8.6	6.5	13.1	11.9
	Richest	**3.8**	3.0	6.4	5.3	15.6	10.0	6.9	5.6	11.8	6.1	**6.8**	**5.0**	**30**	**28.7**	3.0	3.0	5.7	**4.1**	13.2	6.6	5.3	5.3	11.3	9.7	8.1	7.5
Wants another child	Does not want another child	**22.3**	**22.1**	0.0	0.0	**24.3**	**18.9**	11.7	9.5	**31.0**	14.8	**25.3**	**25.3**	**59.8**	**51.0**	**9.6**	**8.8**	11.0	11.0	**18.6**	**15.5**	**17.1**	**17.1**	20.2	13.3	14.6	14.6
	Wants another child	**5.9**	**3.7**	8.7	8.0	**11.2**	**6.3**	9.9	7.8	**10.1**	6.6	**9.9**	**8.5**	**24.9**	**21.9**	**1.4**	**1.3**	10.5	9.4	**10.0**	**5.5**	**7.0**	**5.5**	10.0	8.7	12.8	11.7
Highest level of schooling completed	None or did not complete primary	**13.2**	**10.6**	**10.4**	**9.8**	11.7	7.6	**12.3**	**10.9**	11.8	8.5	**12.1**	**19.8**	**54.0**	**53.4**	4.4	4.4	**13.7**	**12.9**	**17.6**	**14.8**	**22.1**	17.8	12.1	**11.3**	**17.7**	**16.7**
	Primary	**10.4**	**8.1**	**10.0**	**10.0**	14.1	10.0	**7.4**	**6.8**	16.8	13.3	**14.8**	**13.8**	**23.3**	**3.8**	2.5	2.5	**9.6**	**7.2**	**9.7**	**8.7**	**10.8**	10.8	12.2	**11.2**	**16.1**	**14.7**
	Higher than primary school	**6.7**	**4.9**	**5.9**	**4.9**	13.9	8.4	**7.0**	**3.8**	10.5	6.2	**8.6**	**7.5**	**27.1**	**24.4**	5.5	4.9	**5.5**	**4.5**	**10.6**	**5.5**	**8.6**	7.5	8.0	**5.7**	**7.0**	**6.3**
Marital status	Never in union	NA		**1.2**	**1.2**	0.0	0.0	**4.4**	**1.9**	7.2	**3.7**	**2.1**	**2.0**	NA		2.8	2.8	**2.8**	**2.1**	0.0	0.0	**0.4**	**0.4**	4.4	4.4	**3.7**	**3.4**
	Ever in union			**9.5**	**8.7**	13.4	8.4	**13.4**	**11.7**	12.6	**8.3**	**14.6**	**12.9**			5.9	5.3	**12.2**	**11.1**	12.8	8.8	**10.0**	**8.8**	10.8	9.2	**15.4**	**14.2**
Size of first child at birth	Large	10.8	7.4	10.5	9.3	14.9	9.0	11.3	8.4	**13.4**	8.3	8.8	8.6	32.3	22.1	5.0	5.0	9.7	8.7	14.9	12.9	8.5	8.4	8.5	8.0	15	14.1
	Average	6.7	5.1	7.9	7.2	12.1	8.0	8.8	7.1	**7.9**	5.7	11.4	10.0	27.5	25.7	5.3	4.5	8.4	7.4	12.8	8.8	9.9	8.7	11.5	9.6	11.3	10.4

	Small	10.5	7.5	7.8	7.8	12.6	7.5	11.0	9.4	**13.7**	6.7	14.2	12.8	23.3	21.1	3.9	3.9	8.3	6.0	12.2	6.5	4.8	3.3	9.3	7.7	14.8	13.0
Sex of first child	Male	7.6	5.5	9.0	8.2	13.4	7.7	9.9	7.8	11.5	7.1	10.9	9.5	26.7	22.3	5.6	3.9	11.5	10.8	12.2	8.6	10.1	8.9	10.0	8.6	13.6	12.8
	Female	7.6	5.7	8.3	7.7	13.3	9.0	10.0	8.0	10.4	6.7	10.7	9.7	29.2	27.8	5.5	5.3	9.6	8.2	13.5	8.9	7.9	6.8	10.7	9.1	11.9	10.7
Use of contraception	Ever used contraception since first birth	8.1	6.1	8.9	8.2	14.6	7.9	7.3	**4.9**	11.4	6.6	10.9	9.7	**36.5**	**33.5**	5.3	4.9	8.2	**6.2**	12.8	7.7	10.0	9.0	10.0	8.0	11.9	11.1
	No use of contraception since first birth	5.4	3.6	8.4	7.7	11.1	9.1	11.3	**7.5**	10.4	7.3	10.4	9.1	**14.6**	**11.4**	3.8	3.3	11.9	**11.3**	12.9	10.4	6.8	5.5	10.5	9.2	13.6	12.1

Bold values indicate significant chi-square test (p<0.05)

In bivariate analyses (See unadjusted results in Table 4), two countries – Ghana and Senegal – showed that women who delivered their first child by CS had a higher risk of having no subsequent births or pregnancies.

In the multivariate analyses, we found that in four of the thirteen countries (Cambodia, Cote d'Ivoire, Ghana, and Senegal), women who had a cesarean at first birth were at higher risk of having no subsequent pregnancy and no subsequent birth compared with women who delivered vaginally (See Table 4). The magnitude of the association was highest in Cote d'Ivoire, where risk of no subsequent live birth was 21% higher among women who had a cesarean section at first birth compared to vaginal delivery, and risk of no subsequent pregnancy was 20% higher. The magnitude of the association was lowest in Ghana, where risk of no subsequent live birth was 13% higher among women who had a cesarean section at first birth compared to vaginal delivery, and risk of no subsequent pregnancy was 12% higher.

Apart from mode of first birth, not using any contraception since the first birth (12/13 countries) and wanting another child (6/13 countries) were frequently positively associated with having no subsequent births (See Appendix Table 2). In many (8/11) countries where marital status data were available, women who were ever in a marital union had lower risk of having no subsequent births.

Table 4. Incidence Rate Ratios (IRR) of not having a subsequent pregnancy or birth during the follow-up period, by country

Country	Outcome	Caesarean compared with vaginal birth	
		IRR	95% CI
Bangladesh	No subsequent birth, unadjusted	1.06	0.99 – 1.14
	No subsequent birth, adjusted[a]	1.06	0.99 – 1.13
	No subsequent pregnancy, unadjusted	1.05	0.98 - 1.13
	No subsequent pregnancy, adjusted[a]	1.05	0.98 - 1.13
Burkina Faso	No subsequent birth, unadjusted	1.00	0.89 - 1.13
	No subsequent birth, adjusted[b]	1.04	0.92 - 1.18
	No subsequent pregnancy, unadjusted	1.01	0.89 - 1.14
	No subsequent pregnancy, adjusted[b]	1.05	0.92 - 1.19
Cambodia	No subsequent birth, unadjusted	1.10	0.97 - 1.24
	No subsequent birth, adjusted[b]	1.16*	1.04 - 1.30

	No subsequent pregnancy, unadjusted	1.08	0.95 - 1.22
	No subsequent pregnancy, adjusted[b]	1.14*	1.02 - 1.29
Cote d'Ivoire	No subsequent birth, unadjusted	1.12	0.96 - 1.30
	No subsequent birth, adjusted[b]	1.21**	1.05 - 1.40
	No subsequent pregnancy, unadjusted	1.11	0.95 - 1.30
	No subsequent pregnancy, adjusted[b]	1.20*	1.04 - 1.39
Ghana	No subsequent birth, unadjusted	1.11*	1.00 - 1.23
	No subsequent birth, adjusted[b]	1.13*	1.01 - 1.25
	No subsequent pregnancy, unadjusted	1.12*	1.01 - 1.24
	No subsequent pregnancy, adjusted[b]	1.12*	1.01 - 1.25
Jordan	No subsequent birth, unadjusted	1.07	0.91 – 1.26
	No subsequent birth, adjusted[a]	1.07	0.90 – 1.27
	No subsequent pregnancy, unadjusted	1.07	0.90 – 1.27
	No subsequent pregnancy, adjusted[a]	1.07	0.90 – 1.28
Kenya	No subsequent birth, unadjusted	0.99	0.91 - 1.09
	No subsequent birth, adjusted[b]	1.01	0.90 - 1.13
	No subsequent pregnancy, unadjusted	0.99	0.90 - 1.08
	No subsequent pregnancy, adjusted[b]	1.01	0.90 - 1.14
Lesotho	No subsequent birth, unadjusted	1.00	0.86 – 1.15
	No subsequent birth, adjusted[b]	1.01	0.87 – 1.17
	No subsequent pregnancy, unadjusted	0.99	0.86 – 1.14
	No subsequent pregnancy, adjusted[b]	1.00	0.87 – 1.17
Mozambique	No subsequent birth, unadjusted	1.09	0.96 - 1.24
	No subsequent birth, adjusted[b]	1.04	0.91 - 1.18
	No subsequent pregnancy, unadjusted	1.08	0.96 - 1.23
	No subsequent pregnancy, adjusted[b]	1.03	0.90 - 1.17
Nepal	No subsequent live birth, unadjusted	1.01	0.93 - 1.11
	No subsequent live birth, adjusted[b]	1.03	0.93 - 1.14
	No subsequent pregnancy, unadjusted	1.01	0.93 - 1.11
	No subsequent pregnancy, adjusted[b]	1.02	0.92 - 1.14
Philippines	No subsequent birth, unadjusted	1.10	0.98 - 1.23
	No subsequent birth, adjusted[b]	1.10	0.97 - 1.25
	No subsequent pregnancy, unadjusted	1.11	0.99 - 1.24
	No subsequent pregnancy, adjusted[b]	1.11	0.98 - 1.26
Senegal	No subsequent birth, unadjusted	1.17*	1.02 - 1.34
	No subsequent birth, adjusted[b]	1.20*	1.02 - 1.39
	No subsequent pregnancy, unadjusted	1.17*	1.02 - 1.34
	No subsequent pregnancy, adjusted[b]	1.19*	1.02 - 1.40

Tanzania	No subsequent birth, unadjusted	1.10	0.97 - 1.24
	No subsequent birth, adjusted[b]	1.10	0.98 - 1.25
	No subsequent pregnancy, unadjusted	1.10	0.97 - 1.24
	No subsequent pregnancy, adjusted[b]	1.11	0.98 - 1.26

***** p<0.001, ** p<0.01, * p<0.05**

[a] **Covariates**: Maternal age, residence, wealth, education, desire for another child, no contraceptive use since first birth, sex of first child, size of first baby at birth

[b] **Covariates**: Maternal age, residence, wealth, education, marital status, desire for another child, no contraceptive use since first birth, sex of first child, size of first baby at birth

The sensitivity analysis using survival analysis showed that in two countries – Cote d'Ivoire and Burkina Faso – having had a CS at first birth was significantly associated with a longer time to a subsequent birth, when adjusting for other covariates (Cote d'Ivoire: AHR: 0.39, 95% CI: 0.16-0.95, Burkina Faso: AHR: 0.24, 95% CI: 0.13-0.44). No differences were seen with time to subsequent pregnancies. Adjusted Hazard Ratios are found in Appendix Figures 1 and 2.

Discussion

In this retrospective cross-sectional study of women in thirteen low- and middle-income countries, we found that in Cote d'Ivoire, Senegal, Cambodia, and Ghana women who had delivered their first child via cesarean section had a higher risk of no subsequent pregnancy and birth compared women who delivered their first child vaginally. Other variables which were frequently significant across the countries included use of any contraception since the first birth, desire for another child, and marital status (See Appendix Tables 1 and 2). Even controlling for these and other covariates, there was a significant difference in subsequent fertility and fecundity in these four countries, although some of these differences did not retain significance in sensitivity analysis.

These results are consistent with previous studies that have identified lower rates of subsequent conception and childbirth after cesarean compared with vaginal delivery (Kristen H. Kjerulff et al. 2020; K. H. Kjerulff et al. 2013; Mollison et al. 2005; Porter et al. 2003). However our results are inconsistent with previous studies specifically in low- and middle-income countries in Africa, which did not find associations within specific

countries, but did find associations when data across countries was pooled (Collin, Marshall, and Filippi 2006). There are multiple factors which likely contributed to the similarities and differences in our findings compared to earlier works. One of the main factors is the large increases in CS globally means that many more women are exposed to CS than in the 2006 Colin, Marshall, and Filippi paper. The country with the highest CS rate in their study was Zimbabwe with a 7.6% CS rate, while in our study, Mozambique with a 7.2% CS rate was the lowest of the thirteen countries. This trend of increasing CS may have revealed differences which were not large enough to be identified in earlier samples. Recent research has identified CS quality of care in LMIC as poor and shown that women who have CS have a high risk of death and of complications (Sobhy et al. 2019; Bishop et al. 2019). This is in line with one of the main hypotheses as to why women who deliver by cesarean section are less likely to have a subsequent birth.

It may also be the case that women with lower fertility and fecundity have increased risk of delivering by cesarean section (Murphy et al. 2002). In our analysis, three of the four countries where significant differences in subsequent pregnancy and birth are located in West Africa, where higher rates of primary and secondary infertility have been reported previously (Larsen 2000; Ericksen and Brunette 1996). Therefore, our findings could be reflecting overall lower fertility and fecundity in women in certain countries and contexts. Since our data are cross-sectional and our analysis retrospective, we do not have data on how long women were trying to get pregnant before their first birth which would provide insight into this question.

This study is not without limitations. Given its self-reported and retrospective nature, DHS data may be susceptible to reporting and recall error, however fertility estimates from previous DHS surveys have been shown to approximate estimates from prospective longitudinal data and are in general of good or acceptable quality (Schoumaker 2014). Covariates, such as desire for another child, are measured at the time of interview and may have varied over time based on fertility or other factors. The main limitation relates to the period of follow-up. The DHS8 update reduced the recall period from what used to be a five-year recall period for a detailed birth history to a three-year recall period for a detailed

pregnancy history. Information on mode of delivery, that is, vaginal vs. cesarean section, is only available in this detailed history. This means that we only have information on CS exposure from women who had their first birth within the three years prior to the survey. In each country, the average period of reported pregnancy history since first birth for each woman is shorter than the median birth interval (Appendix Table 3). Therefore, the time period available in this analysis may be too short to be able to capture subsequent infertility and infecundity or pregnancies and births in some cases. This may be why the sensitivity analysis using survival analysis showed different results from the main analysis, as survival analysis can be less precise with fewer events in the treatment group (Schober and Vetter 2018). Therefore, the results described here should be interpreted cautiously due to this limited number of subsequent pregnancies and births. However, the findings showing an association of first births by CS and later infertility and infecundity in some contexts suggest that future research with longer periods of follow-up after first birth, and therefore larger numbers of subsequent births, is needed.

Conclusion

The large increases in cesarean deliveries around the world requires more research into the potential implications of this intervention. This analysis is the first to use the new pregnancy history data from the DHS to assess associations between mode of first birth and not only subsequent fertility, but fecundity as well. Our findings suggest that first delivery by cesarean section is associated with a lower risk of subsequent birth in some countries, and may be associated with lower risk of subsequent pregnancy.

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Appendix Table 1. Incidence Rate Ratios of subsequent pregnancy

Appendix Table 1. Incidence Rate Ratios of subsequent pregnancy

		Bangladesh		Burkina Faso		Cambodia		Cote d'Ivoire		Ghana		Jordan		Kenya		Lesotho		Mozambique		Nepal		Philippines		Senegal		Tanzania	
		IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
Mode of first birth (Ref = Vaginal birth)	CS	1.07	0.99 - 1.14	1.05	0.92 - 1.20	1.17 *	1.03 - 1.32	1.22 **	1.05 - 1.41	1.14 *	1.02 - 1.28	1.04	0.87 - 1.25	1.02	0.91 - 1.14	1.01	0.87 - 1.17	1.04	0.91 - 1.18	1.06	0.95 - 1.18	1.09	0.96 - 1.24	1.19 *	1.02 - 1.40	1.10	0.97 - 1.25
Age at first birth (Ref = Less than 30 years of age)	30+ years of age	1.05	0.83 - 1.31	0.67 ***	0.54 - 0.83	0.94	0.82 - 1.08	0.72 ***	0.60 - 0.87	0.96	0.78 - 1.18	0.81	0.63 - 1.03	0.72 *	0.56 - 0.93	0.87	0.68 - 1.12	0.90	0.64 - 1.26	0.98	0.76 - 1.26	0.98	0.86 - 1.12	1.00	0.80 - 1.24	1.04	0.80 - 1.34
Place of residence (Ref = Urban)	Rural	1.01	0.93 - 1.09	0.91 *	0.84 - 1.00	1.07	0.97 - 1.17	1.02	0.91 - 1.15	1.07	0.98 - 1.18	1.21 *	1.00 - 1.47	1.08	0.96 - 1.21	1.02	0.88 - 1.19	0.92	0.82 - 1.03	1.03	0.94 - 1.14	1.03	0.93 - 1.14	0.95	0.86 - 1.05	0.95	0.85 - 1.07
Wealth quintile (Ref =Poorest)	Poorer	1.01	0.90 - 1.12	1.00	0.88 - 1.14	1.1	0.97 - 1.26	0.93	0.76 - 1.14	1.04	0.92 - 1.19	1.18	0.89 - 1.57	1.18	1.00 - 1.40	1.03	0.84 - 1.27	1.04	0.87 - 1.23	1.02	0.88 - 1.18	1.08	0.91 - 1.28	1.00	0.89 - 1.13	0.94	0.79 - 1.12
	Middle	1.05	0.94 - 1.17	1.14 *	1.01 - 1.28	1.04	0.91 - 1.20	0.90	0.75 - 1.09	1.01	0.88 - 1.16	1.36 *	1.02 - 1.82	1.08	0.92 - 1.26	0.96	0.78 - 1.16	1.00	0.84 - 1.19	0.93	0.80 - 1.08	0.98	0.84 - 1.15	1.05	0.91 - 1.21	0.97	0.82 - 1.15
	Richer	1.04	0.93 - 1.16	1.01	0.89 - 1.14	1.05	0.91 - 1.21	0.95	0.79 - 1.15	1.01	0.86 - 1.19	1.27	0.95 - 1.71	1.06	0.92 - 1.23	0.96	0.79 - 1.18	1.25 *	1.03 - 1.52	1.03	0.89 - 1.18	1.06	0.90 - 1.24	1.08	0.94 - 1.24	0.92	0.78 - 1.09
	Richest	1.00	0.89 - 1.12	1.10	0.96 - 1.26	1.01	0.87 - 1.16	1.07	0.88 - 1.29	1.05	0.89 - 1.24	1.20	0.79 - 1.80	1.00	0.84 - 1.18	1.11	0.87 - 1.41	1.25 *	1.03 - 1.53	0.92	0.78 - 1.08	1.05	0.89 - 1.24	0.97	0.84 - 1.12	0.92	0.77 - 1.10
Highest level of schooling completed (Ref =None or did not complete primary)	Primary	0.94	0.80 - 1.10	1.09	0.95 - 1.25	1.04	0.90 - 1.19	0.90	0.71 - 1.14	1.04	0.81 - 1.35	1.49	0.61 - 3.65	1.20	0.96 - 1.50	1.16	0.90 - 1.51	1.03	0.86 - 1.24	1.25 *	1.06 - 1.49	0.95	0.63 - 1.42	1.04	0.81 - 1.34	1.00	0.84 - 1.19
	Higher than primary school	1.03	0.91 - 1.16	1.08	0.99 - 1.19	1.07	0.95 - 1.20	1.13 *	1.00 - 1.26	1.10	0.95 - 1.26	1.25	0.61 - 2.56	1.13	0.94 - 1.37	1.05	0.80 - 1.38	1.05	0.91 - 1.21	1.17 **	1.05 - 1.30	0.95	0.68 - 1.32	1.03	0.94 - 1.14	1.18	1.00 - 1.40
Marital status (Ref = Never in union)	Ever in union	-	-	0.85 **	0.76 - 0.96	1.2	0.92 - 1.56	0.80 ***	0.73 - 0.88	0.86 *	0.76 - 0.96	-	-	0.82 ***	0.74 - 0.91	0.87 *	0.76 - 0.99	0.80 ***	0.70 - 0.91	1.30	0.93 - 1.81	0.97	0.82 - 1.14	0.80 *	0.67 - 0.95	0.82 ***	0.74 - 0.92
Size of first child at birth (Ref = Large)	Average	0.96	0.85 - 1.09	1.01	0.91 - 1.12	1.02	0.93 - 1.12	1.17 **	1.04 - 1.32	1.08	0.97 - 1.20	1.11	0.86 - 1.45	1.01	0.91 - 1.13	1.24 **	1.06 - 1.44	1.05	0.94 - 1.18	1.20 *	1.04 - 1.39	1.02	0.91 - 1.14	0.99	0.87 - 1.11	1.04	0.93 - 1.16
	Small	0.95	0.81 - 1.10	1.04	0.90 - 1.21	1.16	0.98 - 1.38	1.12	0.92 - 1.36	1.07	0.95 - 1.21	1.12	0.80 - 1.56	0.99	0.84 - 1.17	1.18	0.94 - 1.47	1.13	0.94 - 1.36	1.23 *	1.05 - 1.45	1.21 *	1.03 - 1.41	1.09	0.95 - 1.25	0.97	0.79 - 1.19
Sex of first child (Ref = Male)	Female	0.98	0.91 - 1.04	0.95	0.88 - 1.03	1.04	0.94 - 1.14	1.08	0.98 - 1.19	0.95	0.87 - 1.04	0.92	0.77 - 1.10	1.03	0.93 - 1.13	0.94	0.84 - 1.05	0.98	0.89 - 1.09	0.94	0.86 - 1.02	0.99	0.89 - 1.09	1.04	0.95 - 1.14	1.07	0.97 - 1.19
Wants another child (Ref = No)	Wants another child	1.52 ***	1.35 - 1.71	0.85	0.68 - 1.05	1.43 ***	1.25 - 1.64	1.21	0.99 - 1.48	1.17	0.87 - 1.57	1.74 **	1.20 - 2.55	1.34 ***	1.13 - 1.58	1.08	0.95 - 1.22	1.09	0.94 - 1.26	1.20 **	1.08 - 1.34	1.10	0.97 - 1.25	1.02	0.69 - 1.53	1.31 **	1.08 - 1.59
Use of contraception (Ref = Ever	No use of contra	1.30 ***	1.17 - 1.46	1.37 ***	1.26 - 1.49	1.38 ***	1.25 - 1.52	1.24 ***	1.12 - 1.38	1.24 ***	1.11 - 1.37	1.52 ***	1.26 - 1.85	1.29 ***	1.13 - 1.47	1.56 ***	1.28 - 1.90	1.37 ***	1.26 - 1.50	1.39 ***	1.24 - 1.55	1.05	0.93 - 1.19	1.20 **	1.07 - 1.35	1.36 ***	1.23 - 1.50

used since first birth)	ceptio n since first birth																								
Observations		1,994		1,467		1,638		1,400		1,488		858		1,554		675		1,245		1,285		1,453		1,460		1,387	

* = p<0.5, ** = p<0.01, ***=p<0.001

Appendix Table 2. Incidence Rate Ratios of subsequent birth

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		Bangladesh		Burkina Faso		Cambodia		Cote d'Ivoire		Ghana		Jordan		Kenya		Lesotho		Mozambique		Nepal		Philippines		Senegal		Tanzania	
		IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI	IRR	95% CI
Mode of first birth (Ref = Vaginal birth)	CS	1.06	0.99 - 1.13	1.04	0.92 - 1.18	1.16*	1.04 - 1.30	1.21**	1.05 - 1.40	1.13*	1.01 - 1.25	1.07	0.90 - 1.27	1.01	0.91 - 1.13	1.01	0.87 - 1.17	1.03	0.91 - 1.17	1.03	0.93 - 1.14	1.10	0.97 - 1.25	1.19*	1.02 - 1.39	1.10	0.98 - 1.25
Age at first birth (Ref = Less than 30 years of age)	30+ years of age	1.05	0.83 - 1.32	0.67***	0.54 - 0.83	0.92	0.81 - 1.05	0.74***	0.62 - 0.88	0.96	0.79 - 1.16	0.80	0.63 - 1.01	0.72*	0.56 - 0.93	0.87	0.68 - 1.12	0.89	0.63 - 1.26	0.97	0.76 - 1.24	0.98	0.86 - 1.12	0.99	0.80 - 1.24	1.03	0.80 - 1.34
Place of residence (Ref = Urban)	Rural	1.00	0.93 - 1.08	0.91*	0.84 - 1.00	1.05	0.97 - 1.15	1.03	0.92 - 1.16	1.06	0.97 - 1.17	1.21*	1.01 - 1.45	1.07	0.95 - 1.19	1.03	0.89 - 1.19	0.92	0.82 - 1.02	1.02	0.93 - 1.12	1.03	0.94 - 1.14	0.95	0.86 - 1.05	0.96	0.85 - 1.07
Wealth quintile (Ref =Poorest)	Poorer	1.00	0.90 - 1.11	1.01	0.89 - 1.14	1.10	0.97 - 1.25	0.95	0.79 - 1.15	1.03	0.91 - 1.17	1.20	0.92 - 1.55	1.19*	1.01 - 1.40	1.04	0.85 - 1.27	1.04	0.88 - 1.24	1.03	0.89 - 1.18	1.07	0.90 - 1.26	1.00	0.89 - 1.12	0.94	0.80 - 1.12
	Middle	1.05	0.94 - 1.16	1.13*	1.01 - 1.27	1.05	0.92 - 1.19	0.92	0.76 - 1.10	1.02	0.90 - 1.16	1.36*	1.03 - 1.79	1.08	0.92 - 1.26	0.95	0.78 - 1.16	1.00	0.84 - 1.19	0.95	0.83 - 1.10	0.99	0.85 - 1.16	1.05	0.91 - 1.20	0.97	0.82 - 1.14
	Richer	1.04	0.93 - 1.15	1.00	0.89 - 1.14	1.06	0.93 - 1.21	0.96	0.80 - 1.15	1.02	0.87 - 1.20	1.29	0.97 - 1.71	1.06	0.92 - 1.23	0.96	0.79 - 1.18	1.27*	1.05 - 1.54	1.03	0.90 - 1.18	1.06	0.90 - 1.24	1.09	0.95 - 1.24	0.92	0.78 - 1.09
	Richest	0.99	0.89 - 1.11	1.10	0.96 - 1.26	1.01	0.88 - 1.15	1.06	0.88 - 1.28	1.06	0.91 - 1.24	1.17	0.79 - 1.74	1.01	0.85 - 1.19	1.11	0.87 - 1.41	1.26*	1.03 - 1.53	0.95	0.82 - 1.11	1.04	0.88 - 1.22	0.97	0.84 - 1.12	0.92	0.77 - 1.09
Highest level of schooling completed (Ref =None or did not complete primary)	Primary	0.94	0.81 - 1.10	1.09	0.95 - 1.25	1.03	0.90 - 1.18	0.90	0.71 - 1.14	1.04	0.82 - 1.32	1.65	0.72 - 3.81	1.19	0.96 - 1.48	1.16	0.90 - 1.51	1.04	0.87 - 1.24	1.24*	1.05 - 1.47	0.93	0.63 - 1.37	1.04	0.82 - 1.33	1.01	0.85 - 1.20
	Higher than primary school	1.03	0.91 - 1.16	1.10*	1.00 - 1.21	1.06	0.95 - 1.19	1.14*	1.02 - 1.28	1.07	0.95 - 1.22	1.27	0.62 - 2.59	1.12	0.93 - 1.35	1.05	0.80 - 1.38	1.05	0.92 - 1.20	1.19***	1.07 - 1.31	0.94	0.69 - 1.28	1.04	0.95 - 1.15	1.19*	1.00 - 1.41
Marital status (Ref = Never in union)	Ever in union	NA	NA	0.86**	0.77 - 0.96	1.24	0.95 - 1.62	0.80***	0.73 - 0.88	0.86*	0.77 - 0.97	NA	NA	0.83***	0.75 - 0.92	0.86*	0.76 - 0.99	0.80***	0.70 - 0.91	1.31	0.95 - 1.80	0.98	0.83 - 1.15	0.81*	0.68 - 0.96	0.83***	0.75 - 0.92
Size of first child at birth (Ref = Large)	Average	0.95	0.85 - 1.06	1.01	0.91 - 1.11	1.02	0.93 - 1.12	1.16**	1.04 - 1.30	1.07	0.97 - 1.17	1.05	0.84 - 1.32	1.03	0.92 - 1.14	1.23**	1.06 - 1.43	1.05	0.93 - 1.18	1.21**	1.05 - 1.39	1.03	0.92 - 1.15	1.00	0.89 - 1.13	1.04	0.93 - 1.16

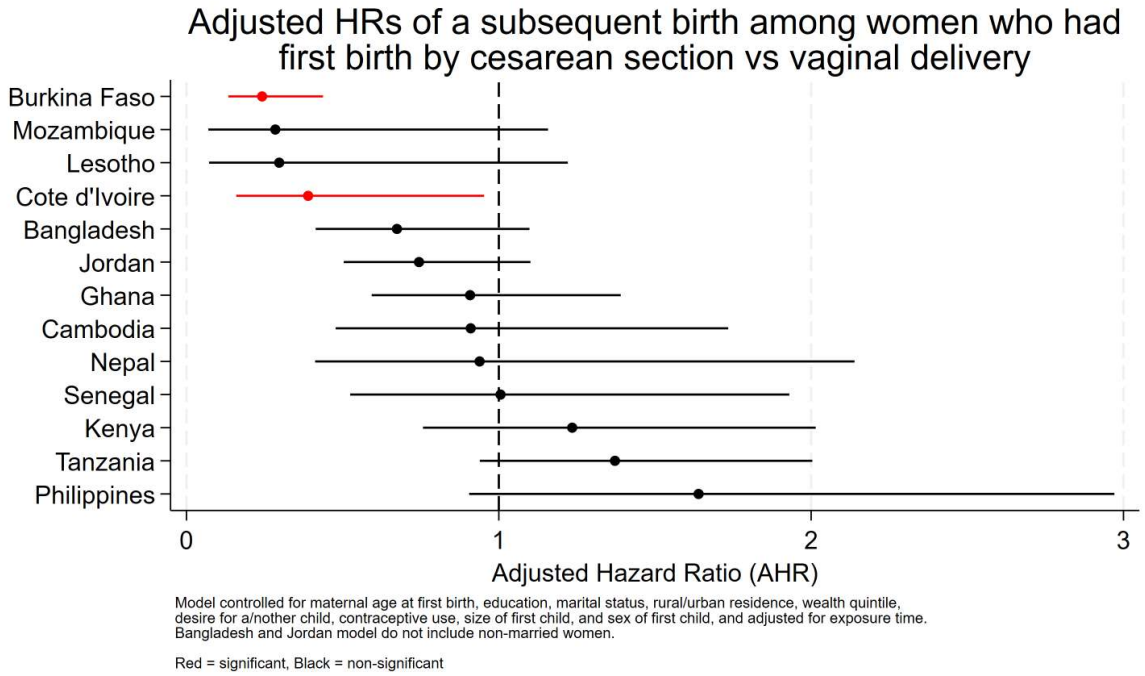
	Small	0.93	0.81 - 1.06	1.03	0.89 - 1.20	1.16	0.99 - 1.35	1.11	0.92 - 1.35	1.08	0.97 - 1.21	1.05	0.78 - 1.42	1.00	0.85 - 1.18	1.18	0.94 - 1.47	1.16	0.98 - 1.37	1.26**	1.07 - 1.47	1.22*	1.05 - 1.43	1.09	0.96 - 1.25	0.98	0.80 - 1.20
Sex of first child (Ref = Male)	Female	0.97	0.91 - 1.04	0.95	0.88 - 1.02	1.03	0.94 - 1.13	1.07	0.98 - 1.18	0.96	0.88 - 1.05	0.90	0.76 - 1.08	1.04	0.94 - 1.14	0.94	0.84 - 1.05	0.99	0.89 - 1.09	0.95	0.87 - 1.03	0.98	0.89 - 1.08	1.04	0.94 - 1.14	1.08	0.98 - 1.19
Wants another child (Ref = No)	Wants another child	1.53***	1.36 - 1.72	0.85	0.68 - 1.05	1.41***	1.24 - 1.60	1.21	1.00 - 1.46	1.15	0.90 - 1.47	1.63**	1.18 - 2.25	1.34***	1.14 - 1.59	1.08	0.95 - 1.22	1.10	0.95 - 1.27	1.21***	1.09 - 1.34	1.12	0.98 - 1.27	0.98	0.69 - 1.38	1.32**	1.08 - 1.60
Use of contraception (Ref = Ever used since first birth)	No use of contraception since first birth	1.31***	1.18 - 1.46	1.37***	1.27 - 1.49	1.34***	1.22 - 1.47	1.24***	1.13 - 1.38	1.22***	1.11 - 1.35	1.53***	1.27 - 1.85	1.29***	1.14 - 1.47	1.55***	1.27 - 1.89	1.36***	1.25 - 1.49	1.36***	1.23 - 1.52	1.06	0.94 - 1.20	1.20**	1.07 - 1.33	1.36***	1.23 - 1.50
Observations		1,994		1,468		1,638		1,400		1,488		857		1,554		675		1,245		1,285		1,452		1,459		1,387	

* = p<0.5, ** = p<0.01, ***=p<0.001

Appendix Table 3. Median birth interval (in months)

Country	Year	Median birth interval in months
Bangladesh	2022	59.2
Burkina Faso	2021	40.4
Cambodia	2021-22	40.6
Cote d'Ivoire	2021	38.7
Ghana	2022	40.6
Jordan	2023	34.7
Kenya	2022	42.1
Lesotho	2023-24	59.4
Mozambique	2022-23	37.1
Nepal	2022	40.7
Philippines	2022	46.5
Senegal	2023	37.6
Tanzania	2022	37.1

Appendix Figure 1



Appendix Figure 2