Unnecessary caesarean section delivery in rural China: exploration of relationships with full-term gestational age and early childhood development

A Yue, W Zheng, S Li *, Q Jiang, Y Li, Y Shi

ABSTRACT

Introduction: Gestational age at delivery is reportedly associated with cognitive and non-cognitive development in early childhood. Delivery at an earlier full-term gestational age has been associated with an increased rate of caesarean section (C-section) delivery; the high rate of C-section delivery in China implies that the rate of medically unnecessary C-section delivery is also high. This study investigated the relationships of medically unnecessary C-section delivery with full-term gestational age and early childhood development in rural China.

Methods: We conducted a survey of 2765 children (aged 5-24 months) who resided in 22 national designated poverty counties. Primary caregivers were interviewed to collect information regarding child and household characteristics (including the child's gestational age), each child's delivery method, and reasons for C-section delivery (if applicable). The children were assessed using the Bayley Scales of Infant Development. Developmental outcomes were compared among gestational age-groups; regression analyses were used to assess relationships among medically unnecessary C-section delivery, gestational age, and developmental outcomes.

Results: Overall, 56.2% of children were born at ≤39 weeks of gestation. Among C-section deliveries, 13.1% were medically necessary and >40% could clearly be classified as medically unnecessary. Repeat C-section was the most common reason given for medically unnecessary C-section delivery. For each 1-week increase in full-term gestational age, cognition scale scores increased by 0.62 points (P<0.01), language scale scores increased by 0.84 points (P<0.01), and motor scale scores increased by 0.55 points (P<0.05). Medically unnecessary C-section delivery was significantly associated with lower full-term gestational age.

Conclusion: Higher full-term gestational age was significantly associated with better childhood developmental outcomes, indicating that medically unnecessary C-section delivery may negatively influence early childhood development.

Hong Kong Med J 2022;28:239–48
https://doi.org/10.12809/hkmj208805

[1] **A Yue,** PhD
[1] **W Zheng,** MD
[1,2] **S Li *,** PhD
[1] **Q Jiang,** MD
[1] **Y Li,** PhD
[1] **Y Shi,** PhD

[1] *Center for Experimental Economics in Education, Shaanxi Normal University, PR China*
[2] *National School of Development, Beijing University, Beijing, PR China*

* Corresponding author: lishanceee@163.com

This article was published on 20 Jun 2022 at www.hkmj.org.

New knowledge added by this study

- Among children born at full term, levels of cognitive, language, and motor development increased with increasing gestational age.
- Caesarean section delivery was negatively associated with gestational age, and a considerable proportion of deliveries in rural China involved medically unnecessary caesarean section.

Implications for clinical practice or policy

- There is a need to reduce the rate of medically unnecessary caesarean section delivery, especially when this delivery method is chosen based on a desire for repeat caesarean section.
- Physicians should carefully consider the potential consequences when they recommend or agree to perform caesarean section delivery; they should also provide detailed information that helps pregnant women to gain greater knowledge about childbirth.

Introduction

Premature birth can influence cognitive development and academic achievement in childhood.[1,2] The final 4 to 5 weeks of gestation, from 37 to 41 weeks, is an important period; children born earlier than this might have risks of worse outcomes later in life.[3,4]

中國農村不必要的剖腹產：足月胎齡和兒童早期發育的關係

岳愛、鄭文庭、李珊珊、蔣琪、史耀疆

引言：分娩時的胎齡與兒童早期認知和非認知發展息息相關。足月胎齡與剖腹產比率上升相關。中國內地的高剖腹產比率可能意味醫學上不必要剖腹產率也很高。本研究檢視中國農村地區醫學上不必要剖腹產與足月胎齡和兒童早期發展的關係。

方法：我們對居住在國家級貧困縣（調研時）的2765名兒童（年齡5-24個月）進行調查。對主要照顧者進行採訪，收集有關兒童和家庭特徵（包括兒童的胎齡）、每個兒童的分娩方式和剖腹產原因（如適用）的信息。使用貝利嬰兒發育量表對兒童進行評估。比較不同孕齡組兒童的發育結果；迴歸分析用於評估醫學上不必要剖腹產、胎齡和兒童發展結果之間的關係。

結果：總體而言，56.2%的兒童在妊娠39週或之前出生。只有13.1%的剖腹產在醫學上是必要的，超過40%的剖腹產可以明確歸類為醫學上不必要的。重複剖腹產是樣本剖腹產最常見的醫學上不必要原因。足月胎齡每增加1週，認知量表得分增加0.62分（P<0.01），語言量表得分增加0.84分（P<0.01），運動量表得分增加0.55分（P<0.05）。醫學上不必要剖腹產與縮短胎齡顯著相關。

結論：對於足月兒童來說，更長胎齡與較好兒童發育結果顯著相關。這表明醫學上不必要剖腹產可能對兒童早期發育產生負面影響。

Substantial brain development occurs during the 37th and 38th weeks of gestation[5,6]; consistent with this developmental timing, higher gestational age has been positively associated with cognitive and motor development in early childhood.[7-9] Additionally, higher full-term gestational age has been positively associated with reading and math achievement in third grade.[10] There is evidence to support the use of 39 weeks of gestation as a threshold for full-term delivery.[11,12] Moreover, the American College of Obstetricians and Gynecologists (ACOG) and the Society for Maternal-Fetal Medicine discourage medically unnecessary delivery before 39 weeks of gestation.[13]

Caesarean section (C-section) is the most common medical intervention associated with delivery at a lower gestational ages.[14] Furthermore, an increased rate of delivery at lower gestational age has been linked to an increased rate of C-section delivery.[15,16] One study found that the rate of elective C-section delivery gradually increased with a change in distribution from 39 weeks to 38 weeks.[17] To our knowledge, no studies have explored the relationship between unnecessary C-section delivery and full-term gestational age. Caesarean section delivery is overused in many countries, often without a clear medical need, because of its convenience and perceived ease.[18] A women's preference can be affected by the belief that C-section delivery is safer for the baby[19]; it can also be affected by an intense fear of childbirth (eg, with nightmares, physical complaints, and anxiety).[20] Some women might deliver by C-section for a specific (or auspicious) birth date or the convenience of returning to full-time employment.[21,22]

Although the ACOG encourages measures to avoid medically unnecessary C-section delivery,[13] the global rate of unnecessary C-section delivery remains high.[18] In China, the rate of C-section delivery is among the highest worldwide (42%-46%)[23,24]; this high rate persists even in rural areas with few resources.[25] In the early 2000s, the World Health Organization (WHO) recommended a rate of C-section delivery below 15% in most populations[26]; a more recent study suggested that a rate of 19% is appropriate.[27] For either threshold, the rate of C-section delivery in China greatly exceeds international recommendations. According to a 2010 WHO report, the high rate of C-section delivery in China implied that the rate of medically unnecessary C-section delivery was also high.[18] While some studies have measured the rate of C-section delivery in China,[28-30] there is no published literature regarding the rate of medically unnecessary C-section delivery in China or other countries.

Considering the potentially high rate of medically unnecessary C-section delivery in China, there is a need to consider its potential associations with full-term gestational age and early childhood development. Thus, this study investigated the relationships of medically unnecessary C-section delivery with full-term gestational age and early childhood development in rural China.

Methods

Sample selection

This study used data that were collected from November 2015 to May 2017 in 22 nationally designated poverty counties located in southern Shaanxi Province, China. In each county, all townships (the administrative level between county and village) were included in the study (Fig), with the following exceptions: the township that served as the seat of each county and townships that did not contain any villages with ≥800 people.

Subsequently, the sample villages and families were selected as follows. To meet the power requirements of a larger, interventional study,[31] a minimum of 10 children was required in each village. Therefore, one village (with ≥10 children in our target age range) was randomly selected from each township. A list of all registered births in the previous 24 months was obtained from the local family planning official in each village. All children in our target age range (5-24 months) were enrolled. Because the present study focused on children born at full term (37-41 weeks of gestation), all children

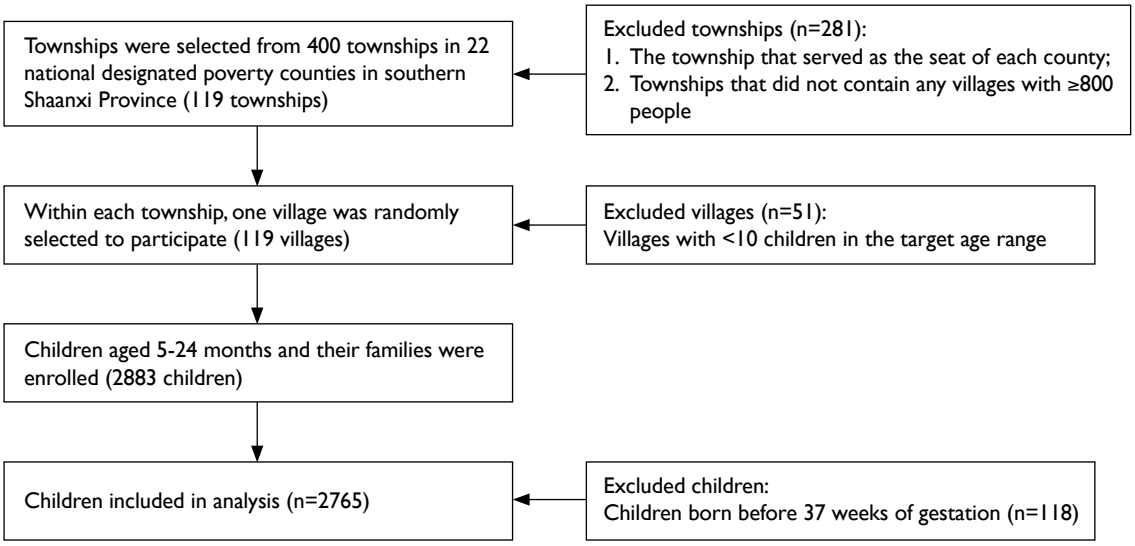

FIG. Flowchart of survey protocol

born before 37 weeks of gestation were removed from the final sample. Regarding variables that did not change with time, data collected in the second part of the survey (described below) were used to impute missing values where possible. Missing values that could not be imputed were excluded from analysis, as were missing values that changed over time. We calculated the mean values of some variables based on the records of missing data. Multiple imputation was conducted to determine whether missing values would influence the results of analysis.

Data collection

In the first part of the survey, teams of trained enumerators collected socio-economic information from all participating households. Each child's primary caregiver (typically the mother or grandmother) was administered a detailed survey regarding child and household characteristics, including each child's sex and birth order, the mother's age and level of education, the father's level of education, and whether the family was receiving government welfare payments (ie, financial support for the lowest-income families nationwide). The family asset index of each household was calculated using principal component analysis[32] based on whether the household owned or had access to the following assets: tap water, flushing toilet, water heater, refrigerator, washing machine, computer, internet, and transportation (motorcycle, car, or truck); the approximate value of the home was also used in the calculation. Each child's age, gestational age (determined by the hospital), and birth weight were obtained from their birth certificate.

In the second part of the survey, each child was administered the third edition of the Bayley Scales of Infant Development (BSID-III). The BSID-III is an internationally recognised assessment for developmental outcomes during early childhood.[33] The BSID-III has high inter- and intra-rater reliability agreement, internal consistency, and test-retest stability, even when tested in other cultural contexts.[33,34] The BSID-III results are categorised into five standardised scales, three of which were used in this study: cognitive (information processing, counting, and number skills), language (receptive and expressive communication skills), and motor (fine and gross motor skills). Each of these scales evaluates a child's performance on a series of interactive tasks, with consideration of the child's gestational and chronological ages. Raw scores for each scale were converted to composite scores in accordance with BSID-III guidelines.[35] These composite scores allowed comparison of developmental levels among children who were born at different gestational ages.

The third and final part of the survey collected information regarding the method of childbirth and the reasons for C-section delivery (if applicable). In accordance with the methodology of previous childbirth surveys,[25,36] we asked whether the delivery had been normal vaginal birth, C-section, or other. For children delivered by C-section, we asked caregivers the open-ended question: "Why did the mother have a C-section?" and recorded all responses. We then collaborated with a paediatrician who was not a co-author of the present study to categorise the reasons as "medically necessary" or "medically unnecessary." Based on a review of international medical and

public health literature, we classified a C-section delivery as "medically unnecessary" if less risky alternatives were available (online supplementary Table 1). The final classifications were carefully reviewed by the paediatrician and adjustments were made as necessary.

TABLE 1. Summary statistics (n=2765)*

Child characteristics	
Sex	
Male	1430 (51.7%)
Female	1335 (48.3%)
Has siblings	
Yes	1416 (51.2%)
No	1349 (48.8%)
Mother is primary caregiver	
Yes	1976 (71.5%)
No	789 (28.5%)
Gestational age	
37 Weeks	175 (6.3%)
≤38 Weeks	600 (21.7%)
≤39 Weeks	1553 (56.2%)
≤40 Weeks	2395 (86.6%)
≤41 Weeks	2709 (98.0%)
≤42 Weeks	2765 (100.0%)
Household characteristics	
Maternal age	
≤25 Years	1852 (67.0%)
>25 Years	913 (33.0%)
Maternal education level	
<12 Years	2139 (77.4%)
≥12 Years	626 (22.6%)
Primary caregiver age	
≤30 Years	1439 (52.0%)
>30 Years	1326 (48.0%)
Primary caregiver education level	
<12 Years	2313 (83.7%)
≥12 Years	452 (16.3%)
Paternal education level	
<12 Years	2004 (72.5%)
≥12 Years	761 (27.5%)
Family asset index†	0.01 ± 1.17
Family receives government welfare payments	
Yes	271 (9.8%)
No	2494 (90.2%)

* Data are shown as No. (%) or mean ± standard deviation

† Asset index was determined using polychoric principal components based on the following variables: tap water, flushing toilet, water heater, refrigerator, washing machine, computer, internet, and transportation (motorcycle, car, or truck)

Statistical analyses

All statistical analyses were conducted using Stata Statistical Software (Version 14.2; StataCorp, College Station [TX], United States). P values of <0.05 were considered significant. Student's *t* test was used to compare childhood developmental outcomes across gestational age-groups. The relationships between gestational age and childhood developmental outcomes were assessed using ordinary least squares regression, with adjustment for the following potential confounders: child characteristics (sex, age, and whether the child had siblings) and household characteristics (whether the mother was the primary caregiver, maternal age, maternal education, paternal education, family asset index, and whether the household received government welfare payments).

Additionally, ordinary least squares regression was used to assess the relationship between unnecessary C-section delivery and gestational age, with adjustment for the potential confounders (child and household characteristics) described above. We also controlled for BSID-III tester (enumerator) fixed effects. In all analyses, we account for clustering within villages using Huber–White cluster-adjusted standard errors.

Results

Participant socio-economic and demographic characteristics

The survey protocol is shown in the Figure. In total, 119 townships were included in the study. We initially enrolled 2883 children aged 5 to 24 months; after exclusion of children born before 37 weeks of gestation, we analysed 2765 children.

The participants' socio-economic and demographic characteristics are shown in Table 1. More than of the children (51.2%) had siblings at the time of the survey. The mother was the primary caregiver for 71.5% of the children. Most mothers (77.4%) had <12 years of education, and one-third of mothers (33.0%) were aged >25 years. Less than one-tenth (9.8%) of sampled families reported receiving government welfare payments.

Table 1 also shows the gestational ages of the surveyed children. Overall, 6.3% of the children were delivered at 37 weeks of gestation, 49.8% were delivered between 38 and 39 weeks, and 41.8% were delivered between 40 and 41 weeks. Only 2% of the children were delivered after 41 weeks of gestation.

Links between gestational age and childhood developmental outcomes

We investigated the relationships between gestational age and childhood developmental outcomes (Table 2). Children with higher gestational ages had higher scores on the cognition, language,

TABLE 2. Relationships between gestational age and childhood developmental outcomes*

	Cognitive scale†		Language scale†		Motor scale†	
	(1)	(2)	(3)	(4)	(5)	(6)
Gestational age	0.63 (0.21)§	0.62 (0.21)§	0.93 (0.24)§	0.84 (0.23)§	0.55 (0.32)	0.55 (0.24)‖
Sex (Ref: Male)		0.52 (0.58)		2.48 (0.58)§		0.42 (0.51)
Age at time of survey (weeks)		0.08 (0.05)		0.47 (0.05)§		1.71 (0.06)§
Has siblings (Ref: No)		-0.87 (0.51)§		-1.21 (0.45)§		-0.54 (0.54)
Mother is primary caregiver (Ref: No)		-0.70 (0.54)		0.54 (0.64)		-0.85 (0.59)
Maternal age (Ref: ≤25 years)		-1.07 (0.52)‖		-0.61 (0.59)		0.17 (0.64)
Maternal education level (Ref: <12 years)		0.58 (0.59)		0.86 (0.74)		0.82 (0.62)
Paternal education level (Ref: <12 years)		1.32 (0.54)‖		1.08 (0.59)		1.55 (0.59)§
Family asset index‡		1.21 (0.26)§		2.24 (0.27)§		1.54 (0.27)§
Constant	66.07 (8.80)§	65.34 (8.99)§	54.04 (9.97)§	49.26 (9.62)§	77.91 (12.54)§	50.96 (9.80)§
Observations	2765	2765	2765	2765	2765	2765
Adjusted R-squared	0.10	0.11	0.09	0.16	0.06	0.36

Abbreviations: BSID-III = third edition of the Bayley Scales of Infant Development; OLS = ordinary least squares

* Data are shown as OLS coefficient (standard errors), based on village-level analysis. Childhood development outcomes were regarded as dependent variables; gestational age was regarded as an independent variable

† Columns (1), (3), and (5) show coefficients for gestational age in OLS regression. Columns (2), (4), and (6) show coefficients for gestational age in OLS regression with adjustment for individual child characteristics and family characteristics. All regressions controlled for BSID-III tester (enumerator) fixed effects, children and household characteristics, including sex (1, female; 0, male), has siblings (1, yes; 0, no), mother is primary caregiver (1, yes; 0, no), maternal age (1, >25 years; 0, ≤25 years), maternal education level (1, ≥12 years; 0, <12 years), and paternal education level (1, ≥12 years; 0, <12 years)

‡ Asset index was determined using polychoric principal components based on the following variables: tap water, flushing toilet, water heater, refrigerator, washing machine, computer, internet, and transportation (motorcycle, car, or truck)

§ P<0.01

‖ P<0.05

and motor scales of the BSID-III. For each 1-week increase in gestational age, cognition scale scores increased by 0.62 points (P<0.01), language scale scores increased by 0.84 points (P<0.01), and motor scale scores increased by 0.55 points (P<0.05). The detailed mean cognition, language, and motor scale scores according to gestational age are shown in the online supplementary Table 2. We also investigated potential non-linear relationships between gestational age and developmental scores by adding a squared term of gestational age to the regression (Table 3). However, the squared term coefficient was not statistically significant for cognitive development. This suggested that gestational age had non-linear relationships with language and development, while it had a linear relationship with cognitive development.

Rate of medically unnecessary caesarean section delivery and reasons for its selection

In our sample, more than one-third (36.4%) of the children were delivered by C-section. Of the medically unnecessary C-section deliveries, 65.2% were performed at ≤39 weeks of gestation (online supplementary Table 3). Table 4 presents the reasons given for C-section delivery. Only 13.1% of C-section deliveries were medically necessary, and >40% of C-section deliveries could clearly be classified as medically unnecessary. Repeat C-section was the most common medically unnecessary reason given for C-section delivery. Additionally, 5.8% of C-section deliveries were performed because the expected date of delivery had passed, whereas 5.3% of C-section deliveries were performed because the amniotic sac had broken. Finally, 4.3% of C-section deliveries were performed because the mother feared pain or desired faster delivery.

Link between unnecessary caesarean section delivery and gestational age

Table 5 shows a series of unadjusted associations between unnecessary C-section delivery and gestational ages. Unnecessary C-section delivery was associated with a significantly greater likelihood of delivery before 39 weeks of gestation. Delivery at ≤39 weeks of gestation was 65% (P<0.01) more likely to involve medically unnecessary C-section, compared with delivery after 39 weeks of gestation. We also found a significant negative association between medically unnecessary C-section delivery and gestational age as a continuous variable. Specifically, gestational age was 0.18 weeks lower (P<0.01) in children delivered by medically unnecessary C-section, compared with children

TABLE 3. Relationships between gestational age and childhood developmental outcomes, analysed with a squared gestational age component*

	Cognitive scale†		Language scale†		Motor scale†	
	(1)	(2)	(3)	(4)	(5)	(6)
Gestational age (weeks)	6.40 (-6.90 to 19.71)	5.22 (-7.57 to 18.02)	15.34 (6.78-23.91)§	12.61 (4.67-20.56)§	22.65 (11.32-33.97)§	14.54 (5.78-23.29)§
Gestational age^2 (weeks)	-0.07 (-0.24 to 0.10)	-0.06 (-0.22 to 0.10)	-0.18 (-0.29 to -0.08)§	-0.15 (-0.25 to -0.05)§	-0.28 (-0.42 to -0.14)§	-0.18 (-0.29 to -0.07)§
Sex (Ref: Male)		0.53 (-0.63 to 1.68)		2.50 (1.36-3.64)§		0.44 (-0.57 to 1.45)
Age at time of survey (weeks)		0.08 (-0.03 to 0.18)		0.47 (0.37-0.57)§		1.70 (1.59-1.82)§
Has siblings (Ref: No)		-0.86 (-1.88 to 0.15)		-1.19 (-2.07 to -0.30)§		-0.52 (-1.60 to 0.56)
Mother is primary caregiver (Ref: No)		-0.69 (-1.75 to 0.37)		0.55 (-0.71-1.80)		-0.84 (-2.00 to 0.32)
Maternal age (Ref: ≤25 years)		-1.08 (-2.10 to -0.05)‖		-0.62 (-1.79 to 0.55)		0.16 (-1.12 to 1.43)
Maternal education level (Ref: <12 years)		0.57 (-0.60 to 1.75)		0.85 (-0.63 to 2.33)		0.81 (-0.42 to 2.05)
Paternal education level (Ref: <12 years)		1.31 (0.24-2.39)‖		1.08 (-0.10 to 2.25)		1.54 (0.38-2.71)§
Family asset index‡		1.21 (0.71-1.72)§		2.23 (1.70-2.77)§		1.54 (1.00-2.07)§
Constant	-48.09 (-311.69 to 215.50)	-25.57 (-279.35 to 228.22)	-230.93 (-403.26 to -58.60)§	-183.45 (-343.61 to -23.30)‖	-358.96 (-585.69 to -132.22)§	-225.39 (-402.00 to -48.79)‖
Observations	2765	2765	2765	2765	2765	2765
Adjusted R-squared	0.10	0.11	0.09	0.16	0.06	0.36

Abbreviations: BSID-III = third edition of the Bayley Scales of Infant Development; OLS = ordinary least squares

* Data are shown as OLS coefficient (95% confidence interval), based on village-level analysis. Childhood development outcomes were regarded as dependent variables; gestational age was regarded as an independent variable

† Columns (1), (3), and (5) show coefficients for gestational age in OLS regression. Columns (2), (4), and (6) show coefficients for gestational age in OLS regression with adjustment for individual child characteristics and family characteristics. All regressions controlled for BSID-III tester (enumerator) fixed effects, children and household characteristics, including sex (1, female; 0, male), has siblings (1, yes; 0, no), mother is primary caregiver (1, yes; 0, no), maternal age (1, >25 years; 0, ≤25 years), maternal education level (1, ≥12 years; 0, <12 years), and paternal education level (1, ≥12 years; 0, <12 years)

‡ Asset index was determined using polychoric principal components based on the following variables: tap water, flushing toilet, water heater, refrigerator, washing machine, computer, internet, and transportation (motorcycle, car, or truck)

§ P<0.01

‖ P<0.05

delivered by medically necessary C-section or possibly medically necessary C-section.

To further explore the relationship between medically unnecessary C-section delivery and gestational age, we conducted a series of multivariate regressions with adjustment for child and household characteristics (Table 6). The results of these analyses were consistent with the findings of the unadjusted analyses: medically unnecessary C-section delivery was significantly associated with lower full-term gestational age.

Discussion

In this study, we found that higher full-term gestational age was positively associated with better developmental outcomes among children aged 5 to 24 months in rural China. This finding is consistent with the growing body of international literature that shows a positive link between gestational age and developmental outcomes among children born at full term.[7,8,10]

However, our data showed a high rate of C-section delivery in rural China, such that 36% of children were delivered by C-section. This rate is substantially higher than the 15% rate recommended by the WHO.[26] It is also higher than the rates in other developing countries, such as Thailand (34.1%) and India (17.8%).[24] Furthermore, nearly half (42.5%) of the C-section deliveries in our sample were medically unnecessary. Although the literature suggests that vaginal delivery after a C-section is safe and reasonable for most women, many C-section deliveries in our study were performed because the mother had a previous C-section. The issue of repeat C-section delivery is particularly relevant in

China since the end of the one-child policy; more families are choosing to have a second child.[37] Our data suggest that many mothers or their physicians ignore or are unaware of current guidelines. To control the high rate of repeat C-section deliveries, additional efforts are needed to inform women and physicians that repeat C-section deliveries are typically unnecessary.

Although painless childbirth methods including pharmacological (systemic analgesia) and nonpharmacological methods (hypnosis) have been developed and widely applied in the past decade,[38] 4.3% of C-section deliveries in this study were performed because the mother feared pain. Other studies have shown that women have an intense fear of vaginal delivery.[39,40] Although this fear contributed to a small percentage of C-section deliveries in our study, our finding suggests that women generally have minimal information about what to expect during delivery and how to cope with labour pain. This lack of information may cause women to feel a lack of control, which can increase their anxiety and cause some women to develop a catastrophic fear of labour.[41,42] In contrast, communication and support between pregnant women and their physicians can greatly improve women's perceptions and experiences of childbirth.[43,44] Physicians also play a key role in performing a C-section delivery when it is medically unnecessary. Physicians may recommend that women deliver by C-section to avoid the medical risks (and accompanying litigation) of vaginal delivery.[20] However, we could not explore this possibility because of data limitations.

In this study, medically unnecessary C-section delivery was negatively associated with full-term gestational age. These findings are consistent with past studies in which gestational age was negatively associated with the rate of C-section delivery (not stratified according to medical need).[14,45] Importantly, our study showed that C-section delivery had reduced full-term gestational age without a clear medical need. Moreover, the significant association between full-term gestational age and childhood development suggested that medically unnecessary C-section delivery could have an impact on early childhood development.

To our knowledge, this is the first study to examine the relationship between medically unnecessary C-section delivery and full-term gestational age. This is also the first study to link medically unnecessary C-section delivery and gestational age to childhood developmental

TABLE 4. Reasons for caesarean section delivery (n=1006)*

	Frequency
Medically unnecessary reasons	428 (42.5%)
Mother feared pain/wanted faster delivery	43 (4.3%)
Mother was aged >35 years	22 (2.2%)
Exceeded expected date of delivery	58 (5.8%)
Amniotic sac was broken	53 (5.3%)
Premature rupture of membranes	2 (0.2%)
Twins or in vitro fertilisation	13 (1.3%)
Repeat caesarean section	204 (20.3%)
Presumed very large fetus (birth weight <4000 g)	33 (3.3%)
Possibly medically necessary reasons	446 (44.3%)
Improper fetal position	94 (9.3%)
Poor maternal health (high blood sugar/hypertension/ heart disease)	66 (6.6%)
Mother was overweight or underweight	4 (0.4%)
Excessive/insufficient amniotic fluid	60 (6.0%)
Amniotic fluid contamination	15 (1.5%)
Presumed very large fetus (birth weight ≥4000 g)	21 (2.1%)
Small pelvic bone	7 (0.7%)
Cord around neck	43 (4.3%)
Insufficient cervical dilation	16 (1.6%)
Reason unknown/physician preference	120 (11.9%)
Medically necessary reasons	132 (13.1%)
Dystocia/failure to progress	82 (8.2%)
Uterine/placental complications	14 (1.4%)
Poor fetal health	36 (3.6%)

* Data are shown as No. (%)

TABLE 5. Relationships between gestational age and medically unnecessary caesarean section delivery*

	No.	Gestational age								Gestational age, weeks
		37 Weeks		≤38 Weeks		≤39 Weeks		≤40 Weeks		
		Percentage	P value	Percentage	P value	Percentage	P value	Percentage	P value	
Medically unnecessary caesarean section	428	7% ± 26%	0.29	25% ± 43%	<0.1	65% ± 48%	<0.01	89% ± 32%	0.19	-0.18†
All other births	2337	6% ± 24%		21% ± 41%		55% ± 50%		86% ± 34%		

* Data are shown as mean ± standard deviation. All regressions controlled for BSID-III tester (enumerator) fixed effects. A *t* test was used to test whether the mean proportion of medically unnecessary caesarean section deliveries significantly differed according to gestational age.

† P<0.01

TABLE 6. Relationships between gestational age and medically unnecessary caesarean section delivery[*] [†]

	Gestational age				Gestational age
	37 Weeks	≤38 Weeks	≤39 Weeks	≤40 Weeks	
Medically unnecessary caesarean section delivery (Ref: No)	0.01 (-0.02 to 0.04)	0.04 (-0.01 to 0.09)	0.11[‡] (0.05-0.16)	0.02 (-0.01 to 0.05)	-0.16[‡] (-0.29 to -0.02)
Sex (Ref: Male)	0 (-0.02 to 0.03)	-0.02 (-0.04 to 0.01)	-0.06[‡] (-0.10 to -0.02)	-0.02[§] (-0.05 to 0.00)	0.10[‡] (0.01-0.19)
Has siblings (Ref: No)	0.02[§] (0.01-0.04)	0.03[§] (0.00-0.06)	0.07[‡] (0.04-0.11)	0.04[‡] (0.01-0.07)	-0.16[‡] (-0.24 to -0.08)
Mother is primary caregiver (Ref: No)	-0.01 (-0.03 to 0.01)	-0.03 (-0.07 to 0.01)	-0.06[§] (-0.11 to -0.01)	-0.05[‡] (-0.08 to -0.02)	0.17[‡] (0.06-0.27)
Maternal age (Ref: ≤25 years)	0 (-0.02 to 0.02)	-0.04[§] (-0.08 to -0.00)	-0.02 (-0.06 to 0.02)	-0.02 (-0.05 to 0.01)	0.08[§] (-0.01 to 0.18)
Maternal education level (Ref: <12 years)	-0.01 (-0.03 to 0.01)	-0.01 (-0.05 to 0.03)	0 (-0.05 to 0.05)	-0.01 (-0.06 to 0.03)	0.04 (-0.08 to 0.15)
Paternal education level (Ref: <12 years)	0.01 (-0.01 to 0.04)	0.02 (-0.02 to 0.06)	0.02 (-0.03 to 0.07)	0.02 (-0.02 to 0.05)	-0.09 (-0.20 to 0.02)
Family asset index	0 (-0.01 to 0.01)	0.01 (-0.01 to 0.03)	0 (-0.02 to 0.02)	0 (-0.01 to 0.02)	-0.02 (-0.07 to 0.03)
Constant	0.06 (-0.10 to 0.22)	0.07 (-0.08 to 0.23)	0.22[‡] (0.06-0.38)	0.77[‡] (0.58-0.97)	39.93[‡] (39.37-40.49)
Observations	2765	2765	2765	2765	2765
Adjusted R-squared	0.01	-0.00	0.03	0.01	0.01

[*] Data are shown as ordinary least squares coefficient (95% confidence interval), based on village-level analysis

[†] All regressions controlled for BSID-III tester (enumerator) fixed effects, children and household characteristics, including caesarean section delivery (1, yes; 0, no), sex (1, female; 0, male), has siblings (1, yes; 0, no), mother is primary caregiver (1, yes; 0, no), maternal age (1, >25 years; 0, ≤25 years), maternal education level (1, ≥12 years; 0, <12 years), and paternal education level (1, ≥12 years; 0, <12 years). Asset index was determined using polychoric principal components based on the following variables: tap water, flushing toilet, water heater, refrigerator, washing machine, computer, internet, and transportation (motorcycle, car, or truck)

[‡] P<0.01

[§] P<0.05

outcomes. Our findings highlight the importance of avoiding C-section delivery for non-medical reasons, especially before 39 weeks of gestation.

Physicians should carefully consider the implications of our findings before they recommend or agree to perform C-section delivery. Moreover, physicians should understand the consequences of performing C-section deliveries at lower full-term gestational ages; our study and previous literature[7,8] suggest that these consequences include worse developmental outcomes. In particular, physicians should consider whether a woman has reached 39 weeks of gestation because the ACOG strongly discourages medically unnecessary C-section delivery before 39 weeks.[13] Considering that repeat C-section is the most common reason for medically unnecessary C-section delivery, physicians and pregnant women should be informed that vaginal delivery after a previous C-section is a safe and feasible option for women without other medical reasons to deliver by C-section. Finally, given that some women request C-section delivery because they fear pain, we recommend that physicians and hospitals establish consultation and support systems to help pregnant women understand what to expect during delivery and to provide guidance concerning labour pain relief. Increased communication and support from physicians and nurses has been shown to reduce the fear of childbirth that leads some women to request C-section delivery[41]; such approaches may also be effective in China.

There were four main limitations in this study. First, because the recorded reasons for C-section delivery were based on caregiver recall, we could not rule out the potential for recall bias. Second, although we included adjustment for potential confounding factors, many other potential confounding factors might have influenced the findings. Third, our survey sample comprised villages in one low-income region of rural China. Although we attempted to sample villages that differed in terms of household income, population size, distance from the county seat, and geographic location, our sample might not be representative of all households in rural China. Finally, our study sought to improve the understanding of medically unnecessary C-section delivery and its associations with gestational age and childhood developmental outcomes—we could not regard these as causal associations because of the cross-sectional nature of our dataset. Therefore, in the absence of further analysis, we could not determine whether medically unnecessary C-section delivery was associated with suboptimal childhood developmental outcomes, and we could not characterise the mechanisms that underlay associations identified in our study. Future

research is needed to clarify the pathophysiological mechanisms by which medically unnecessary C-section delivery among children born at full term is negatively associated with early childhood developmental outcomes.

Conclusion

Among children born at full term, levels of cognitive, language, and motor development increased with increasing gestational age. However, C-section delivery was negatively associated with gestational age. A considerable proportion of deliveries in rural China involved medically unnecessary C-section. Therefore, the rate of medically unnecessary C-section delivery, especially when this delivery method is chosen based on a desire for repeat C-section, should be reduced. Physicians should carefully consider the potential consequences when they recommend or agree to perform C-section delivery; they should also provide detailed information that helps pregnant women to gain greater knowledge about childbirth.

Author contributions

Concept or design: S Li, A Yue.
Acquisition of data: A Yue.
Analysis or interpretation of data: S Li, A Yue.
Drafting of the manuscript: S Li, W Zheng, Q Jiang, Y Li, Y Shi.
Critical revision of the manuscript for important intellectual content: A Yue.

All authors had full access to the data, contributed to the study, approved the final version for publication, and take responsibility for its accuracy and integrity.

Conflicts of interest

As an International Editorial Advisory Board member of the journal, Y Shi was not involved in the peer review process. Other authors have disclosed no conflicts of interest.

Acknowledgement

The authors thank Dr Y Gao for contributing to the interpretation of data with this study.

Funding/support

This study was supported by a grant from the National Natural Science Foundation of China (Ref 71703083). The funder had no role in study design, data collection/analysis/interpretation or manuscript preparation.

Ethics approval

This study was approved by the Stanford University Institutional Review Board (Ref 35921). Informed consent was obtained from all participants involved in the study.

References

1. Groeschel S, Tournier JD, Northam GB, et al. Identification and interpretation of microstructural abnormalities in motor pathways in adolescents born preterm. NeuroImage 2014;87:209-19.
2. Peterson BS, Vohr B, Staib LH, et al. Regional brain volume abnormalities and long-term cognitive outcome in preterm infants. JAMA 2000;284:1939-47.
3. Yang S, Bergvall N, Cnattingius S, Kramer MS. Gestational age differences in health and development among young Swedish men born at term. Int J Epidemiol 2010;39:1240-9.
4. Davis EP, Buss C, Muftuler LT, et al. Children's brain development benefits from longer gestation. Front Psychol 2011;2:1.
5. Zacharia A, Zimine S, Lovblad KO, et al. Early assessment of brain maturation by MR imaging segmentation in and premature infants. AJNR Am J Neuroradiol 2006;27:972-7.
6. Kinney HC. The near-term (late preterm) human brain and risk for periventricular leukomalacia: a review. Semin Perinatol 2006;30:81-8.
7. Rose O, Blanco E, Martinez SM, et al. Developmental scores at 1 year with increasing gestational age, 37-41 weeks. Pediatrics 2013;131:e1475-81.
8. Espel EV, Glynn LM, Sandman CA, Davis EP. Longer gestation among children born full term influences cognitive and motor development. PLoS ONE 2014;9:e113758.
9. Yang S, Platt RW, Kramer MS. Variation in child cognitive ability by week of gestation among healthy term births. Am J Epidemiol 2010;171:399-406.
10. Noble KG, Fifer WP, Rauh VA, Nomura Y, Andrews HF. Academic achievement varies with gestational age among children born at term. Pediatrics 2012;130:e257-64.
11. Spong CY. Defining "term" pregnancy: recommendations from the Defining "Term" Pregnancy Workgroup. JAMA 2013;309:2445-6.
12. Reddy UM, Bettegowda VR, Dias T, Yamada-Kushnir T, Ko CW, Willinger M. Term pregnancy: a period of heterogeneous risk for infant mortality. Obstet Gynecol 2011;117:1279-87.
13. American College of Obstetricians and Gynecologists. ACOG Committee Opinion No. 761: cesarean delivery on maternal request. Obstet Gynecol 2019;133:e73-7.
14. Davidoff MJ, Dias T, Damus K, et al. Changes in the gestational age distribution among U.S. singleton births: impact on rates of late preterm birth, 1992 to 2002. Semin Perinatol 2006;30:8-15.
15. Bettegowda VR, Dias T, Davidoff MJ, Damus K, Callaghan WM, Petrini JR. The relationship between cesarean delivery and gestational age among US singleton births. Clin Perinatol 2008;35:309-23, v-vi.
16. Ananth CV, Vintzileos AM. Trends in cesarean delivery at preterm gestation and association with perinatal mortality. Am J Obstet Gynecol 2011;204:505.e1-8.
17. Nassar N, Schiff M, Roberts CL. Trends in the distribution of gestational age and contribution of planned births in New South Wales, Australia. PLoS One 2013;8:e56238.
18. Gibbons L, Belizan JM, Lauer JA, Betran AP, Merialdi M, Althabe FX. The global numbers and costs of additionally needed and unnecessary caesarean sections performed per year: overuse as a barrier to universal coverage. World health report 2010;30:1-31.
19. Weaver JJ, Statham H, Richards M. Are there "unnecessary" cesarean sections? Perceptions of women and obstetricians about cesarean sections for nonclinical indications. Birth 2007;34:32-41.

20. Bettes BA, Coleman VH, Zinberg S, et al. Cesarean delivery on maternal request: obstetrician-gynecologists' knowledge, perception, and practice patterns. Obstet Gynecol 2007;109:57-66.
21. Penna L, Arulkumaran S. Cesarean section for non-medical reasons. Int J Gynecol Obstet 2003;82:399-409.
22. Karlström A, Nystedt A, Johansson M, Hildingsson I. Behind the myth—few women prefer caesarean section in the absence of medical or obstetrical factors. Midwifery 2011;27:620-7.
23. Mi J, Liu F. Rate of caesarean section is alarming in China. Lancet 2014;383:1463-4.
24. Lumbiganon P, Laopaiboon M, Gülmezoglu AM, et al. Method of delivery and pregnancy outcomes in Asia: the WHO global survey on maternal and perinatal health 2007-08. Lancet 2010;375:490-9.
25. Long Q, Klemetti R, Wang Y, Tao F, Yan H, Hemminki E. High caesarean section rate in rural China: is it related to health insurance (New Co-operative Medical Scheme)? Soc Sci Med 2012;75:733-7.
26. World Health Organization, United Nations Children's Fund. Monitoring Emergency Obstetric Care: a Handbook. Geneva: World Health Organization; 2009.
27. Molina G, Weiser TG, Lipsitz SR, et al. Relationship between cesarean delivery rate and maternal and neonatal mortality. JAMA 2015;314:2263-70.
28. Sufang G, Padmadas SS, Fengmin Z, Brown JJ, Stones RW. Delivery settings and caesarean section rates in China. Bull World Health Organ 2007;85:755-62.
29. Deng W, Klemetti R, Long Q, et al. Cesarean section in Shanghai: women's or healthcare provider's preferences? BMC Pregnancy Childbirth 2014;14:285.
30. Li HT, Ye R, Achenbach TM, et al. Caesarean delivery on maternal request and childhood psychopathology: a retrospective cohort study in China. BJOG 2011;118:42-8.
31. Qian Y, Zheng YM, Dill SE, Rozelle S. Correlates of participation in community-based interventions: evidence from a parenting program in rural China. PLoS One 2020;15:e0238841.
32. Luo R, Shi Y, Zhou H, et al. Anemia and feeding practices among infants in rural Shaanxi Province in China. Nutrients 2014;6:5975-91.
33. Madaschi V, Mecca TP, Macedo EC, Paula CS. Bayley-III scales of infant and toddler development: transcultural adaptation and psychometric properties. Paidéia 2016;26:189-97.
34. Azari N, Soleimani F, Vameghi R, et al. A psychometric study of the Bayley scales of infant and toddler development in Persian language children. Iran J Child Neurol 2017;11:50-6.
35. Bayley N. Bayley Scales of Infant and Toddler Development. 3rd ed. San Antonio (TX): Harcourt Assessment; 2006.
36. Xiao S, Yan H, Shen Y, et al. Utilization of delivery care among rural women in China: does the health insurance make a difference? A cross-sectional study. BMC Public Health 2010;10:695.
37. Liang J, Mu Y, Li X, et al. Relaxation of the one child policy and trends in cesarean section rates and birth outcomes in China between 2012 and 2016: observational study of nearly seven million health facility births. BMJ 2018;360:k817.
38. Aksoy M, Aksoy AN, Dostbil A, Celik MG, Ince I. The relationship between fear of childbirth and women's knowledge about painless childbirth. Obstet Gynecol Int 2014;2014:274303.
39. Campbell DA, Lake MF, Falk M, Backstrand JR. A randomized control trial of continuous support in labor by a lay doula. J Obstet Gynecol Neonatat Nurs 2006;35:456-64.
40. Hodnett ED, Gates S, Hofmeyr GJ, Sakala C. Continuous support for women during childbirth. Birth 2005;32:72.
41. Flink IK, Mroczek MZ, Sullivan MJ, Linton SJ. Pain in childbirth and postpartum recovery: the role of catastrophizing. Eur J Pain 2009;13:312-6.
42. Cheung W, Ip WY, Chan D. Maternal anxiety and feelings of control during labour: a study of Chinese first-time pregnant women. Midwifery 2007;23:123-30.
43. Wang E. Requests for cesarean deliveries: the politics of labor pain and pain relief in Shanghai, China. Soc Sci Med 2017;173:1-8.
44. Geissbuehler V, Eberhard J. Fear of childbirth during pregnancy: a study of more than 8000 pregnant women. J Psychosom Obstet Gynecol 2002;23:229-35.
45. MacDorman MF, Mathews TJ, Martin JA, Malloy MH. Trends and characteristics of induced labour in the United States, 1989-98. Paediatr Perinat Epidemiol 2010;16:263-73.