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ORIGINAL RESEARCH ARTICLE

Association of birth by cesarean section with academic performance and intelligence in youth: A cohort study

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Abstract

Introduction: It is suggested that birth by elective cesarean section (CS) reduces the risk of birth-related infant mortality and injury. Other studies suggest an increased risk of somatic immune-related diseases among children born by CS such as asthma, type 1 diabetes, and inflammatory bowel disease. The WHO Statement on Cesarean Section Rates 2015 described an increase in CS globally. The statement concluded that the effects of CS on social and psychological outcomes remain unclear and that more research is needed to fully understand the effects of CS, including effects on cognition and intelligence in the child. Therefore, we aimed to investigate the association between delivery by CS (elective and acute) and school performance and intelligence in youth.

Material and methods: This cohort study included all Danish live-born children in 1978–2000. We retrieved data regarding pregnancies, births, parents, school grades, and intelligence of the children from Danish registers and performed multiple imputations to avoid discarding data. The final cohort after exclusion comprised 1 408 230 children. Associations between CS and school graduation, grades, conscription attendance, and conscription intelligence scores were analyzed using univariate and multivariate logistic and linear regressions.

Results: Adjusted odds ratio with 95% CI of graduating from lower (LSE) and upper (USE) secondary education and of attending conscription were significantly lower in the CS group: LSE graduation: 0.87 (0.84–0.89), USE graduation: 0.93 (0.92–0.94), attending conscription: 0.95 (0.93–0.98). The CS group had significantly lower grade point averages (GPA) in LSE with adjusted differences in mean total GPA of −0.090 (−0.10 to −0.007), and mean core subject GPA of −0.098 (−0.11 to −0.08), in USE with total GPA difference of −0.091 (−0.11 to −0.075) and lower mean intelligence scores of −0.36 (−0.46 to −0.27) in adjusted linear models. A sub-analysis revealed lower chances of graduating LSE and USE when born by acute rather than elective CS.

Abbreviations: BPP, Børge Priens Prøve; CI, confidence interval; CS, cesarean section; GPA, grade point average; ICD8, International Classification of Diseases, 8th revision; ICD10, International Classification of Diseases, 10th revision; LSE, lower secondary education; MBR, Danish Medical Birth Registry; NPR, Danish National Patient Registry; OPR, classification of surgical procedures codes from 1977 to 1995; OR, odds ratio; SKS, classification of surgical procedures codes from 1996 till present; USE, upper secondary education.

Conclusions: Chances of LSE and USE graduation and of attending conscription were significantly lower for children born by CS. However, even significant differences in mean GPAs and intelligence scores were very small, so performances when graduating school and attending conscription were comparable regardless of delivery mode.

KEYWORDS
cesarean section, cognitive function, delivery mode, educational outcome, intelligence, school performance

1 | INTRODUCTION

It has been suggested that birth by elective cesarean section (CS) reduces the risk of birth-related infant mortality and injury. On the other hand, different risk factors are associated with the surgical procedure for the mother as well as for the infant, and the overall risk of morbidity and mortality is higher for the woman compared with vaginal delivery.[1,2]

Multiple studies suggest a possible increased risk of somatic immune-related diseases among children born by CS such as asthma, type 1 diabetes, and inflammatory bowel disease.[3–5]

The WHO Statement on Cesarean Section Rates from April 2015 described an increase in CS globally in high-income as well as low- and middle-income countries. The statement concluded among others that the effects of CS on social and psychological outcomes remain unclear and that more research is needed to fully understand the health effects of CS on future outcomes.[6] Subsequent cognition and intelligence in the child in childhood, adolescence, and adulthood are some of these uncovered areas.

A few other studies have found associations between mode of delivery and later cognitive function.[7,8] Opposite studies have found improved cognitive function among children born by CS,[9] or no association.[10–12]

This study aimed to investigate the association between delivery by CS (elective and acute) and school performance in adolescence and intelligence in early adulthood.

Key message

Delivery by cesarean section was associated with lower chances of passing lower and upper secondary education and attending conscription but not with poorer results when passing or attending.

2 | MATERIAL AND METHODS

2.1 | Study population

This cohort study is based on all liveborn children in Denmark in the period 1978–2000 ($n = 1\,450\,681$).

In Denmark, every infant receives a unique social security number used by public authorities. The number identifies a person throughout life across different public authorities and registers.

The cohort was defined as all registered liveborn children in the Danish Medical Birth Registry (MBR) in the period. MBR contains data on all liveborn children in Denmark since 1968, their parents and the pregnancies. The register has and does evolve both in term of registered variables and registration practice, causing some variables to change over time.[13,14]

Some of the data for this study were either registered poorly or not registered at all in MBR. Therefore, we also accessed the Danish National Patient Registry (NPR) to retrieve further information on the children and their mothers. The NPR has existed since 1977 and includes information on all somatic inpatients. Since 1995 the register furthermore contains data on all outpatients and patients from emergency rooms and psychiatric wards. Since 1995 NPR has been used as source-register for MBR.[15,16] The contact date, associated diagnoses codes (International Classification of Diseases, 8th and 10th revision [ICD8] and [ICD10]) and if relevant, codes from the classification of surgical procedures, called OPR codes (1977–1995) and SKS codes (1996 up until present) are registered in NPR.

2.2 | Cesarean section

Data on CS was retrieved from MBR and NPR. If the child's mother was registered with an OPR or SKS code indicating CS between 2 weeks before and 20 weeks after the date of birth, the child was registered as born by CS. Some codes after 1995 contain information on whether the procedure was elective or acute, others are unspecified. If a child or mother appeared with an unspecified CS code, we checked if they were registered with a specified ICD10 CS code to decide if the procedure was elective or acute. Finally, we searched for children registered with a CS in MBR. MBR has distinguished between elective and acute CS since 1995.

The OPR, SKS, ICD8, and ICD10 codes are listed in Table S1.

2.3 | School grades

In Denmark, Primary and lower secondary education (LSE) consists of 10 years of education in the age span of approximately 6 to 16 years. When ending LSE, the students receive grades from their

final examinations and final annual grades reflecting their daily performance in class during the year. The current Danish grading system was introduced in 2007 and consists of the 7-point grading scale with numeric grades and corresponding letter grades according to the EU ECTS grading scale. The possible grades are −3 (F), 00 (Fx), 02 (E), 4 (D), 7 (C), 10 (B), and 12 (A); −3 being the lowest possible score and 12 the highest possible score. The minimum grade for passing an examination or subject is 02[17] and 7 is the expected medium ranking.[18] All grades given before 2007 were converted to the 7-point grading scale according to the Ministry of Higher Education and Science.[17]

The Danish general upper secondary education programs (USE) are qualifying for access to higher education. The duration of the programs is normally 2–3 years, and usually USE is initiated directly after LSE or after an 11th year of voluntary LSE, ie most students are 16–17 years old when initiating USE. As in LSE, the results on the final diploma are most often a combination of examination grades and final annual grades.

In the study period there have been numerous changes in school subjects, and in addition each student must choose to specialize in different subjects at different levels, making the possible combinations of subjects numerous. Consequently, we performed analyses on both the total grade point average (GPA) including all examination and final annual grades and GPA for the core subjects Danish, Mathematics, and English, which have been mandatory at the final examination during all the years.

2.4 | Intelligence

Data on the male children's intelligence in young adulthood were obtained from the Danish Conscription Registry. This has existed since 1987 and contains information on all men and women who have appeared before a Danish Conscription Board for assessment before military or civil service. According to the Danish constitution, all Danish male citizens must appear before the board unless one of the board's doctors declare the person unfit for service before the examination because of severe and well-documented somatic or psychiatric disorders.[19] The examinations at the conscription board include an intelligence test, the Børge Priens Prøve (BPP), and a physical examination.[20]

The BPP has included the same items since 1956. The test consists of four individually timed subtests of 17–24 items comprising numeric, logical, verbal, and spatial tasks. In total, there are 78 items and the final test score is the sum of correct answers making 78 the highest possible score.[19,21] Teasdale et al showed that the correlation between BPP score and educational level has remained stable through the 1990s and 2000s, that the BPP has a satisfactory test–retest reliability, and that the test scores are not positively associated with expressed attitude to being called upon to serve conscription, supporting the reliability of the BPP in relation to cognitive ability.[21] Furthermore Mortensen et al showed that the BPP correlates 0.82 with the full-scale Wechsler Adult Intelligence Scale and is therefore suited to epidemiological studies of intelligence.[22]

We retrieved the total BPP scores and dates of registration from the Danish Conscription Registry.

An overview of the cohort and the different analyses is given in Figure 1.

2.5 | Covariates

Before data collection, we identified possible confounders based on directed acyclic graphs (Figure S1).[23]

The following variables were considered potential confounders: gestational age, sex of the child, birthweight, congenital malformations, breech presentation, delivery complications, interventions during delivery (vacuum extraction or forceps delivery), multiple pregnancy, parity, maternal chronic disease, mother's age at time of delivery, civil status of the mother (parents living together or not), maternal educational level, paternal educational level, and ethnicity of the child.

When possible, data on covariates were retrieved from MBR. Some variables were not included or were poorly registered for some, or all, of the study period. These variables were retrieved from NPR instead, and if a variable in NPR was not sufficient for all years, the gaps were completed with data from MBR when possible.

Data on gestational age, sex of the child, birthweight, breech presentation, interventions during delivery, multiple pregnancy, and mother's age were obtained from MBR and were available for the entire study period.

Data on delivery complications were obtained from NPR and included the diagnoses pre-eclampsia, placental insufficiency, placenta previa, placental abruption, uterine rupture, and umbilical complications. Only the umbilical complications variable was supplemented with data from MBR in the period 1978–1986. The diagnoses were included if they were registered between 1 week before and 1 week after the date of birth (2 weeks for pre-eclampsia) to avoid diagnoses from earlier or later pregnancies of the mother. The included ICD8 and ICD10 diagnostic codes are listed in Table S2.

Data on congenital malformations were obtained from NPR and MBR in the periods 1978–1996 and 1997–2002, respectively. Congenital malformations were defined as ICD8 codes 74xxx and 75xxx and ICD10 codes DQxxx exclusive of all minor malformations according to Eurocat's guideline from 2005.[24]

The diagnoses and corresponding ICD8 and ICD10 codes for maternal chronic diseases were defined according to the comorbidity index reported by Jølving et al[25] Data were collected from NPR, and we included all registered diagnoses before the date of delivery.

The parity of the mother was available in MBR for children born between 1996 and 2000. For children born between 1982 and 1996 we searched through the cohort to see if the mother of a child was registered with one or more previous deliveries. For children born in 1978–1981 the parity of the mother was decided by multiple imputation.

Statistics Denmark provided data on parental educational level at time of birth. All mothers were successfully identified through

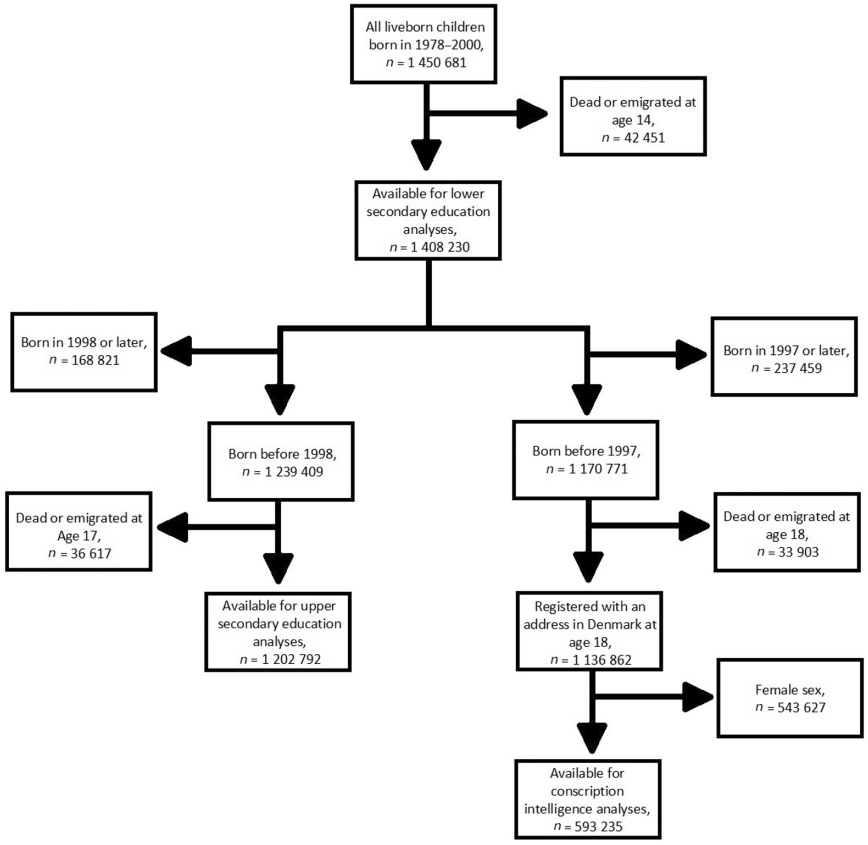

FIGURE 1 Flowchart of the study cohort.

Statistics Denmark and only 10 834 (0.8%) of the fathers were unidentified. The educational level at the time of birth was available from Statistics Denmark for 96% and 98% of the identified fathers and mothers, respectively.

The maternal marital status was available as married/unmarried for the period 1978–1986. For 1986–2000 Statistics Denmark provided data on whether the children were living with two adults 1 year after birth, enabling the variable "parents living together".

The ethnicity of the children was provided by Statistics Denmark, and all children were categorized as either Danish or descendants of an immigrant, as immigrated children not born in Denmark were not included in our cohort.

2.6 | Statistics

Statistical analyses were performed using R-studio and SAS 9.4 TS Level 1 M3.

We performed univariate and multivariable logistic and linear regression analyses. The results are presented as odds ratios (OR) or regression coefficients with 95% confidence intervals (CI).

Missing values appeared in the variables gestational age, birthweight, marital status of the mother, educational level of the mother and the father, and ethnicity of the child. To avoid discarding data we performed multiple imputations in R-studio using the package MICE. Ten imputations of five iterations were carried out for all the missing values.

We performed post hoc analyses with data stratified on term and preterm birth. We also performed post hoc analyses with exclusion of multiple pregnancies and children with congenital malformations, and with exclusion of breech presentation, multiple birth, congenital malformations, and preterm and post-term delivery. They did not reveal a different distribution in any of the analyses.

2.7 | Ethics statement

This study was approved by the Danish Data Protection Agency with the approval number: HGH-2017-015. According to Danish law, register-based follow-up studies do not require approval from ethical committees or patient consent.

3 | RESULTS

The final cohort consisted of 1 450 681 live-born children and contained 1 294 519 (86%) children born by vaginal delivery and 201 262 (14%) children born by CS. Characteristics of the cohort are listed in Table 1. The proportion of male children, delivery complications, breech presentation, multiple pregnancies, primiparous mothers, mothers with chronic diseases, and children dead or emigrated were highest in the CS group. Mean gestational age, birthweight, and interventions during delivery were lower in the CS group. The

TABLE 1 Characteristics of pregnant women and their children born in Denmark in 1978–2000.[a]

Characteristics	Vaginal delivery	Cesarean section
Number (%) (*N* = 1 450 681)	1 249 419 (86.13)	201 262 (13.87)
Sex, *n*[b] (%)		
Male	648 810 (51.93)	108 061 (53.69)
Female	600 609 (48.07)	93 201 (46.31)
Missing	0 (0)	0 (0)
Ethnicity, *n* (%)		
Danish	1 166 787 (93.39)	187 890 (93.36)
Second-generation immigrant	72 560 (5.81)	9553 (4.75)
Missing	10 072 (0.81)	3819 (1.90)
Parents living together, *n* (%)		
Together	1 047 946 (83.87)	167 824 (83.39)
Apart	193 910 (15.52)	30 642 (15.22)
Missing	7563 (0.61)	2796 (1.39)
Paternal education, *n* (%)		
Very short	936 008 (74.92)	150 094 (74.58)
Short	42 634 (3.41)	7056 (3.51)
Medium	134 398 (10.76)	21 611 (10.74)
Long	86 569 (6.93)	14 383 (7.15)
Missing	49 810 (3.99)	8118 (4.03)
Maternal education, *n* (%)		
Very short	921 136 (73.23)	147 299 (73.19)
Short	39 107 (3.13)	6578 (3.27)
Medium	214 196 (17.14)	35 331 (17.55)
Long	45 663 (3.65)	7741 (3.85)
Missing	29 317 (2.35)	4313 (2.14)
Mother's age, years (SD)[c]	27.73 (4.81)	28 569 (5.07)
Missing, *n* (%)	0 (0)	0 (0)
Maternal chronic disease,[d] *n* (%)		
Yes	52 663 (4.21)	15 346 (7.62)
No	1 196 756 (95.79)	4 185 916 (92.38)
Missing	0 (0)	0 (0)
Maternal parity, *n* (%)		
Primipara	487 753 (39.04)	98 779 (49.08)
Multipara	549 103 (43.95)	177 515 (38.51)
Missing	212 563 (12.07)	24 968 (12.41)
Delivery complications,[e] *n* (%)		
Yes	32 574 (2.61)	16 973 (8.43)
No	1 216 845 (97.39)	184 289 (91.57)
Missing	0 (0)	0 (0)
Interventions during delivery,[f] *n* (%)		
Yes	126 020 (10.09)	5688 (2.83)
No	1 123 399 (89.91)	195 574 (97.17)
Missing	0 (0)	0 (0)

TABLE 1 (Continued)

Characteristics	Vaginal delivery	Cesarean section
Breech presentation, *n* (%)		
Yes	14 068 (1.13)	50 018 (24.85)
No	1 235 351 (98.87)	151 244 (75.15)
Missing	0 (0)	0 (0)
Mean gestational age, weeks (SD)	39.67 (1.70)	38.52 (2.82)
Missing, *n* (%)	0 (0)	0 (0)
Gestational age, *n* (%)		
Extremely preterm <28 weeks	1837 (0.15)	1249 (0.62)
Very preterm 28–31 weeks	3457 (0.28)	5385 (2.68)
Moderate preterm 32–36 weeks	40 553 (3.25)	24 609 (12.23)
Term 37–40 weeks	1 035 063 (82.84)	145 386 (72.24)
Post term >40 weeks	103 884 (8.31)	16 997 (8.45)
Missing	64 625 (5.17)	7636 (3.79)
Mean birthweight, g (SD)	3459.58 (543.94)	3215.64 (795.96)
Missing	10 281 (0.82)	1884 (0.94)
Apgar score at five minutes, *n* (%)		
0–3	4.018 (0.32)	1673 (0.83)
4–6	5216 (0.42)	3287 (1.63)
7–10	1 223 815 (97.95)	193 076 (95.76)
Missing	16 370 (1.31)	3226 (1.60)
Multiple pregnancy, *n* (%)		
Yes	21 554 (1.73)	18 612 (9.25)
No	1 227 865 (98.28)	182 650 (90.75)
Missing	0 (0)	0 (0)
Dead or emigrated, *n* (%)		
At age 14	34 632 (2.77)	7819 (3.88)
At age 17	35 883 (2.87)	7959 (3.95)
At age 18	35 245 (2.82)	7866 (3.91)
Missing	0 (0)	0 (0)

[a]Observed data.

[b]Number.

[c]Standard deviation.

[d]Diabetes mellitus and non-insulin-dependent diabetes mellitus, thyroid disorders, parathyroid disorders, Cushing syndrome, polycystic ovary syndrome, polyglandular dysfunction, polyarthritis nodosa, rheumatoid arthritis, systemic lupus erythematosus, inflammatory bowel disease, epilepsy, multiple sclerosis, hypertension, ischemic heart disease, chronic heart disease, cardiovascular diseases, atherosclerosis, coagulation disorders, chronic lung disease, including asthma, HIV, mood disorders, schizophrenia/other paranoid psychoses, and anxiety and personality disorders.

[e]Pre-eclampsia, placental insufficiency, placenta previa, placental abruption, uterine rupture, and umbilical complications.

[f]Vacuum extraction or forceps delivery.

distributions of ethnicity, parents living together, and parental education were comparable for the two groups.

3.1 | Educational outcomes

The observed educational outcomes are listed in Table 2. A slightly higher proportion of children born vaginally graduated from LSE compared with the CS group. The mean core subject GPAs were comparable and the statistically significant differences in mean total GPAs and mean grades for English and mathematics were 0.05 grades or lower.

A slightly higher proportion of children born vaginally graduated from USE. Children born vaginally received statistically significantly higher mean total and core subject GPAs; statistically significant differences in mean grades were also observed for the subjects Danish and mathematics, but all differences were between 0.02 and 0.09 grade points.

Table 3 shows that the OR of graduating from LSE and USE was statistically significantly lower in the CS group in both unadjusted and adjusted analyses. Tables S3A and S3B show that chances of graduating from both LSE and USE were statistically significantly lower for the children delivered by acute CS compared with elective CS and with vaginal delivery.

Table 4 shows that for LSE, the adjusted total and core subject GPAs were statistically significantly lower in the CS group. For USE, the total mean GPA was statistically significantly lower in both the unadjusted and adjusted models. All differences remained less than 0.1 grade points, corresponding to 1%–4% of the standard deviation of the vaginal delivery group. Tables S4A and S4B show that differences between mean grades following acute and elective CS were small and of no clinical relevance.

3.2 | Intelligence scores at conscription

Table 2 shows results for intelligence. The percentage of male children who appeared before the conscription and the mean BPP intelligence score were lowest for the CS group.

Table 3 shows that the OR of attending conscription was significantly lower for the CS group in both unadjusted and adjusted models. Tables S5A and S5B show no significant differences in the corresponding OR when comparing elective and acute CS in adjusted models.

Table 4 presents the results for BPP scores. The CS group had significantly lower mean BPP scores with an adjusted difference of −0.36 (−0.46 to −0.27), corresponding to about 4% of the vaginal delivery group standard deviation. Tables S6A and S6B show no significant differences in mean BPP test scores when comparing elective and acute CS in adjusted models.

The adjusted chance of graduating LSE, USE, and of being called upon for conscription was not statistically different between preterm and term children. Grades in LSE were consistently slightly lower among preterm than term children. However, for USE, the average grades of preterm children were slightly higher than those of term children. In any case, these differences did not appear to be of a clinically relevant magnitude (Tables S7–S9).

Analyses with exclusion of multiple pregnancies and congenital malformations and analyses with exclusion of breech presentation, multiple birth, congenital malformations, and preterm and post-term delivery did not reveal any different distributions (Tables S10–S14).

4 | DISCUSSION

Our results showed that children delivered by CS had lower chances of graduating from LSE and USE and of attending conscription. The CS group also obtained slightly lower GPAs in LSE and USE as well as lower mean BPP intelligence scores. The magnitude of the adjusted OR of passing LSE and USE seems clinically relevant, but the differences in OR of attending conscription were too small to be of clinical significance. Also, the differences in mean GPAs and mean BPP test scores were negligible compared with the observed standard deviations.

Earlier studies on the association between mode of delivery and later cognitive function used different outcome measures including intelligence, learning disability, and school achievements. The results are inconsistent as to why the possible association remains unresolved.[11,9,7,26,8]

Among Swedish school-aged children, Curran et al found slightly higher OR of poor school performance and slightly lower mean grades in children born by either type of CS,[7] supporting our results. Nielsen and Bergsjøo found lower intelligence among Norwegian draft-liable men born by CS, but only when placenta previa was the indication for the CS. The results are difficult to compare with ours, as we did not have access to the indication for the CS. In contrast, Sprung et al found lower risks of learning disabilities among American 5-year-old children born by CS compared with vaginal delivery if the mother had received regional anesthesia.[9] Again, the results are hard to compare, as we did not have access to data concerning anesthesia. Eide et al found no significant association between mode of delivery and low scores at the Norwegian military intelligence test[25] and McBride et al,[11] Smithers et al,[12] Khadem and Khadivzadeh,[26] and Hong-tian et al[27] found no association, in contrast to our results.

The strengths of this study are primarily the amount of available data and the sample size with ~1.4 million live-born children. The nationwide follow up of all pregnancies limits the risk of selection bias,[28] and the prospective data collection in our follow-up design tends to suggest non-differential misclassification.[29] We were able to look at a wide time span and include relevant and potential confounders with relatively low amounts of missing data thanks to the national registers, leaving little room for residual confounding.[23] Although confounding by indication is, theoretically, a potential problem, few differences were apparent between women giving

TABLE 2 Educational and intelligence outcome of children born in Denmark in 1978–2000[a].

Variable	Vaginal delivery	Cesarean section	*p* value	Participants with no grades *n*[b] (%)
Lower secondary education, *n* (%) (*N* = 1 408 230)	1 214 787 (86.26)	193 443 (13.74)	–	N/A[c]
Graduated lower secondary education, *n* (%)			<0.001	N/A
Yes	1 165 786 (95.97)	184 028 (95.13)		
No	49 001 (4.03)	9451 (4.87)		
Registered with at least four grades, *n* (%)			<0.001	N/A
Yes	756 308 (62.26)	124 382 (64.30)		
No	458 479 (37.74)	69 061 (35.70)		
Total grade average, mean (SD[d])	6.44 (2.27)	6.45 (2.25)	<0.001	527 540 (37.46)
English grade average, mean (SD)	6.66 (3.04)	6.71 (3.02)	<0.001	527 531 (37.46)
Danish grade average, mean (SD)	6.49 (2.27)	6.49 (2.26)	0.73	527 531 (37.46)
Mathematics grade average, mean (SD)	6.55 (2.77)	6.50 (2.76)	<0.001	527 531 (37.46)
Core subjects grade average, mean (SD)	6.57 (2.47)	6.57 (2.43)	0.96	527 531 (37.46)
Upper secondary education, *n* (%) (*N* = 1 202 792)	1 040 799 (86.53)	161 993 (13.47)	–	N/A
Graduated upper secondary education, *n* (%)			<0.001	N/A
Yes	571 929 (54.95)	187 752 (54.17)		
No	468 870 (45.05)	74 241 (45.83)		
Registered with at least four grades, *n* (%)			<0.001	N/A
Yes	546 751 (52.53)	85 251 (52.63)		
No	494 048 (47.47)	76 742 (47.37)		
Total grade average, mean (SD)	6.58 (2.1)	6.56 (2.0)	<0.001	570 790 (47.46)
English grade average, mean (SD)	6.41 (2.70)	6.41 (2.71)	0.93	571 116 (47.48)
Danish grade average, mean (SD)	6.45 (2.44)	6.41 (2.43)	<0.001	571 090 (47.48)
Mathematics grade average, mean (SD)	5.87 (3.31)	5.78 (3.31)	<0.001	629 931 (52.37)
Core subjects grade average, mean (SD)	6.25 (2.37)	6.21 (2.33)	<0.001	630 319 (52.40)
Conscription, *n* (%) (*N* = 593 235)	511 240 (86.18)	81 995 (13.82)	–	N/A
Appearance before conscription board, *n* (%)			<0.001	N/A
Yes	381 680 (74.66)	159 633 (72.73)		
No	129 560 (25.34)	22 362 (27.27)		
BPP[e] score, mean (SD)	42.81 (9.93)	42.45 (10.00)	<0.001	149 951 (25.28)

[a]Observed data.
[b]Number.
[c]Not applicable.
[d]Standard deviation.
[e]Børge Priens Prøve.

birth vaginally or by CS, and the differences observed were accounted for in the multivariable analyses.

The main limitation is our missing information on whether the CS were acute or planned during the early inclusion period. Furthermore, we do not have information on the reason for the intervention. We have indirectly accounted for this by adjusting for covariates that might cause both elective and acute CS such as placenta previa, multiple pregnancy, and delivery complications. Based on data for the period 1995–2000, analyses revealed lower chances of graduating from LSE and USE for children delivered by acute CS compared with elective. Chances of appearing before a draft board, mean grades, and IQ scores were not significantly different for the two groups. Given that these associations are unlikely to have changed over time, the sub-analyses are likely to be representative.

TABLE 3 Logistic model showing the association between mode of delivery and graduating lower secondary school and upper secondary school and being called to the conscription board.

OR[a] of passing education	Cesarean section	Vaginal delivery
	n[b] = 193 443	*n* = 1 214 787
Unadjusted Lower secondary education (95% CI[c])	0.82 (0.80–0.84)	Reference
Adjusted[d] Lower secondary education (95% CI)	0.87 (0.84–0.89)	Reference
	n = 161 933	*n* = 1 040 799
Unadjusted Upper secondary education (95% CI)	0.97 (0.96–0.98)	Reference
Adjusted[c] Upper secondary education (95% CI)	0.93 (0.92–0.94)	Reference
	n = 81 995	*n* = 511 240
Unadjusted Conscription (95% CI)	0.91 (0.89–0.92)	Reference
Adjusted[d] Conscription (95% CI)	0.95 (0.93–0.97)	Reference

[a]Odds ratio.

[b]Number.

[c]Confidence interval.

[d]Adjusted for: sex, gestational age, birthweight, delivery complications, breech presentation, interventions during delivery, congenital malformations, multiple pregnancy, parity of the mother, mother's age, maternal chronic disease, maternal educational level, paternal educational level, marital status of the mother, and ethnicity of the child.

TABLE 4 Linear model showing the association between mode of delivery and school grades and conscription intelligence test scores.

Educational level	Cesarean section	Vaginal delivery
	n[a] = 193 443	*n* = 1 214 787
Lower secondary education total mean average (95% CI[b]), unadjusted	0.0074 (−0.0062 to 0.021)	Reference
Lower secondary education core subject mean average (95% CI), unadjusted	0.00034 (−0.015 to 0.014)	Reference
Lower secondary education total mean average (95% CI), adjusted[c]	−0.090 (−0.10 to −0.077)	Reference
Lower secondary education core subject mean average (95% CI), adjusted[c]	−0.098 (−0.11 to −0.08)	Reference
	n = 161 933	*n* = 1 040 799
Upper secondary education total mean average (95% CI), unadjusted	−0.03 (−0.04 to −0.01)	Reference
Upper secondary education total mean average (95% CI), adjusted[c]	−0.091 (−0.11 to −0.075)	Reference
	n = 81 995	*n* = 511 240
BPP[d] test score, mean (95% CI), unadjusted	−0.34 (−0.43 to −0.26)	Reference
BPP test score, mean (95% CI), adjusted[c]	−0.36 (−0.46 to −0.27)	Reference

[a]Number.

[b]Confidence interval.

[c]Adjusted for: sex, gestational age, birthweight, delivery complications, breech presentation, interventions during delivery, congenital malformations, multiple pregnancy, parity of the mother, mother's age, maternal chronic disease, maternal educational level, paternal educational level, marital status of the mother, and ethnicity of the child.

[d]Børge Priens Prøve.

5 | CONCLUSION

Overall, compared with children born vaginally, children born by CS performed equally well at LSE, USE, and at the conscription intelligence test (for young men). However, chances of graduating from LSE or USE and of appearing before a draft board were significantly lower for children born by CS, though the difference was small concerning conscription. These results may add to the discussion of pros and cons in relation to the widespread use of CS worldwide.

AUTHOR CONTRIBUTIONS

AKL conceptualized and designed the study, collected data, carried out analysis and interpretation of data, drafted the initial manuscript, and reviewed and revised the manuscript. JAS collected data and reviewed and revised the manuscript. FJB and EPFS conceptualized and designed the study, collected data, and reviewed and revised the manuscript. ELM conceptualized and designed the study and reviewed and revised the manuscript. SL carried out analysis and interpretation of data and reviewed and revised the manuscript.

USK conceptualized and designed the study, interpreted data, and reviewed and revised the manuscript.

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CONFLICT OF INTEREST STATEMENT

Steen Ladelund is an employee of and holds shares in Novo Nordisk A/S. The other authors have indicated they have no potential conflicts of interest to disclose.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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