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ORIGINAL RESEARCH ARTICLE

Association of Apgar score at 5 minutes with academic performance and intelligence in youth: A cohort study

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Abstract

Introduction: The Apgar score is routinely given at childbirth worldwide. A low Apgar score at 5 minutes is a strong predictor for neonatal death. Scores below 7 have been associated with higher risks of later neurologic disability. Few studies have assessed the association between Apgar score and school performance and intelligence. The existing literature points towards a possible association between Apgar score and later cognitive function, but the contradictions call for further investigation to fully understand the potential association. This study aimed to examine the possible association between Apgar score at 5 minutes and academic performance and intelligence in youth.

Material and methods: The study is a cohort study. The cohort consists of all Danish liveborn children in 1978–2000 (n = 1 450 681). Data regarding pregnancies, births, parents, school grades, and intelligence of the children were retrieved from different Danish registers. Multiple imputations were performed to avoid discarding data. After exclusion, the final cohort consisted of 1 005 241 children. Associations between Apgar score at 5 minutes and school graduation, grades and attendance, and intelligence scores from conscription were analyzed using univariate and multivariate logistic and linear regressions.

Results: No association was found between Apgar score and graduating primary school. Adjusted odds ratio (aOR) of graduating upper secondary education and attending conscription were significantly lower for children with scores below 7 compared with 7–10: graduating upper secondary education: Apgar 0–3: aOR 0.79 (95% CI 0.67–0.93), Apgar 4–6: aOR 0.86 (95% CI 0.81–0.93), attending conscription: Apgar 0–3: aOR 0.73 (95% CI 0.59–0.91), Apgar 4–6: aOR 0.73 (95% CI 0.66–0.80). The Apgar 4–6 group had significantly lower total mean primary school grade average: −0.13 (95% CI −0.21 to −0.054) and lower mean intelligence scores at conscription: −0.57 (95% CI −1.09 to −0.058). All other differences remained insignificant.

Abbreviations: AS5, Apgar score at 5 minutes; BPP, Børge Prien Prøve; ICD, International Classification of Diseases; PS, primary and lower secondary school; USE, upper secondary education.

Conclusions: Performances when graduating school and attending conscription were overall equal regardless of Apgar score at 5 minutes. Chances of graduating primary school were the same irrespective of the score, but chances of graduating upper secondary education and attending conscription were significantly lower with scores below 7. The results suggest that children with scores below 7 may fail to appear at upper secondary education and conscription, but if they do, they perform equally to anyone else.

KEYWORDS
academic performance, Apgar score, cognitive function, intelligence, school performance

1 | INTRODUCTION

The Apgar score is a standardized assessment of the newborn's need for immediate care. The score is routinely given at 1 and 5 minutes. A low score at 5 minutes is a strong predictor for neonatal death.[1] Scores less than 7 at 5 minutes have been associated with higher risks of later neurologic disability,[2] seizures,[3] cerebral palsy,[4] epilepsy,[5] intellectual disability,[4] motor impairments,[6] attention déficits,[4] and speech and language problems.[7]

Few studies have assessed the association between Apgar score and school performance and intelligence. An association between low Apgar scores and poor educational outcomes in childhood[8,9] and lower intelligence in childhood and adolescence[6,10] have been shown. However, associations between low Apgar score and low intelligence[11] and educational achievements[10] are absent in other studies.

The existing literature points towards a possible association between Apgar score and later cognitive function but the contradictions call for further investigation to fully understand the potential association.

We aimed to investigate the association between Apgar score at 5 minutes (AS5) and school performance and intelligence in youth.

Key message

The association between Apgar score and later cognitive function is unclear. Apgar score below 7 at 5 minutes was associated with lower chances of graduating upper secondary education and attending conscription but not with lower results when graduating or attending.

2 | MATERIAL AND METHODS

2.1 | Study population

The cohort was defined as all registered liveborn children in the The Danish Medical Birth Register (MBR) in the period 1978–2000 (*n* = 1 450 681). MBR has existed since 1968. The registry contains data on all liveborn children in Denmark, the pregnancies, and the parents.[12,13]

The Danish National Patient Registry (NPR) supplemented data in cases of insufficiency in MBR. NPR has existed since 1977 and includes information on all somatic inpatients. Since 1995, NPR also contains data on all outpatient, emergency room, and psychiatric ward contacts.[14,15] NPR contains data on the dates of the contacts, the associated International Classification of Diseases, Revision 8 and 10 diagnosis codes (ICD8 and ICD10) and if relevant the codes from the Classification of Surgical Procedures (OPR codes [1977–1995] and SKS codes [1996 onwards]).

A unique personal identification number linked information from the registers. MBR and NPR have been validated elsewhere.[12,14]

2.2 | Exposure

The Apgar score was introduced in 1952 and was developed to evaluate the clinical condition of newborns immediately after birth. The score is the sum of ratings (0–2) of five different clinical signs; heart rate, respiratory effort, reflex irritability, muscle tone, and skin color.[16] The score is assigned by a midwife, obstetrician or pediatrician present at the birth. 10 is the highest possible score and describes the best possible condition of the infant. All scores of 7 or more indicate good to excellent condition, scores of 4–6 are moderately abnormal, and scores of 3 or less are low.[17] Therefore the children were grouped into 0–3, 4–6 and 7–10 Apgar groups.

The AS5 was registered in MBR throughout the entire time of the register's existence. We discovered an obvious, different distribution of data in the years 1991–1996 with 100 times more children registered with AS5 0 than in the years before and after. It was not possible to identify the true scores for these children, and sensitivity analyses revealed a very different association with outcomes during the period. For this reason, we excluded all children born in this period (*n* = 414 837).

2.3 | Outcomes

2.3.1 | School grades

In Denmark, primary and lower secondary school (PS) consists of 10 years of education from approximately 6 to 16 years of age. The students receive grades from their final examinations as well as final grades of the year reflecting their daily performance in class. The upper secondary education (USE) programs of 2–3 years are qualifying for access to higher education. The usual age at graduation is 18–20 years. Each student must choose different subjects at different levels, resulting in numerous possible combinations.

The current Danish grading system was introduced in 2007 and consists of a seven-point grading scale with numeric grades and corresponding letter grades according to the EU European Credit Transfer and Accumulation System grading scale. The possible grades are: −3 (F), 00 (Fx), 02 (E), 4 (D), 7 (C), 10 (B), and 12 (A). The minimum grade for passing an examination or subject is 02,[18] and 7 is the expected median ranking.[19] All grades given before 2007 on the previous 00–13 grading scale were converted to the seven-point scale according to the Ministry of Higher Education and Science.[18]

For PS and USE we used the examination grades and the final grades of the year. For PS we performed analyses on the total average and the average of the core subjects Danish, Mathematics and English, which have been mandatory at the final examination throughout the study period. For USE we only performed analyses on the total average.

If a child was registered with at least four grades from the end of PS and/or USE, they were included with their total average in our analyses regardless of whether they had graduated or not.

We did not have data on school grades after 2017, so we only included children born before 1998 in the USE analyses, making the youngest children in our analysis 20 years of age.

Children without an address in Denmark at age 14 or 17 years, who were therefore either dead or emigrated, were excluded from PSE and USE analyses, respectively (n = 30 603 and n = 3588).

2.3.2 | Intelligence

Data on male intelligence in youth were obtained from the Danish Conscription Registry. This registry has existed since 1987 and contains information on all men who have appeared before a Danish Conscript 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 declares the person unfit for service due to severe and well-documented somatic or psychiatric disorders.[20] All men are called for conscription the year they turn 18, but it is possible to postpone the date due to education, and therefore most men are between 18 and 20 years old, when they meet the board.[21,22] The conscription board's examinations include an intelligence test, the Børge Prien Prøve (BPP), and a physical examination.[23] The BPP has remained unchanged since 1956 with the exact same items; it consists of four individually timed subtests of 17–24 items involving respectively logical, verbal, numeric, 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.[20,24] The correlation between BPP score and educational level has remained stable through the 1990s and 2000s, supporting the reliability of the BPP in relation to cognitive ability, further characteristics including validation exist elsewhere.[24]

We retrieved the registration dates and total results of the BPP up until 2017 from the Danish Conscription Registry, so we included male children born before 1997 with an address in Denmark at age 18 in the analyses (n = 383 075). An overview of the cohort is given in Figure 1.

2.4 | Co-variates

Potential confounders were identified a priori based on directed acyclic graphs. The following variables were considered: sex and ethnicity of the child, gestational age, birthweight, birth complications, breech presentation, cesarean section, interventions during delivery (vacuum extraction or forceps delivery), congenital malformations, multiple pregnancy, parity of the mother, marital status of the mother (parents living together or not), maternal educational level, chronic disease, age at delivery, and paternal educational level.

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

Data on birth complications were obtained from NPR and included: preeclampsia, umbilical complications, uterine rupture, placenta previa, and placental abruption. Umbilical complications were supplemented with data from MBR in the period 1978–1986. The diagnoses were included if they were registered between 1 week of gestational age and 1 week after date of birth (2 weeks for preeclampsia). The diagnosis codes are listed in Table S1.

Data on cesarean section were obtained from both MBR and NPR for the entire period, the diagnosis codes are listed in Table S2.

Data on congenital malformations were obtained from NPR in the period 1978–1996 and from MBR in the period 1997–2002. Congenital malformations were defined as all 74xxx and 75xxx ICD8 codes and all DQxxx ICD10 codes excluding all minor malformations according to the Eurocat guideline from 2005.[25]

The mother's parity was available in MBR in 1996–2000. For 1981–1996 we calculated the mother's parity based on earlier births of children in the register and for 1978–1981 the parity was decided by multiple imputation.

Maternal chronic disease was defined according to the comorbidity index reported by Jølving et al.[26] Data were collected from the NPR, and we included all registered diagnoses up until the date of birth.

Statistics Denmark provided data on parental educational level, marital status of the mother, and ethnicity of the children. All mothers were identified through Statistics Denmark, whereas 9235 (0.9%) of the fathers were unidentified. The marital status of the mothers was only available as married/unmarried in the period 1978–1986. After 1986, Statistics Denmark provided data on whether the child was living with two adults 1 year after birth, thus providing the status "parents living together". Ethnicity of the children was categorized as either Danish or descendant of an immigrant.

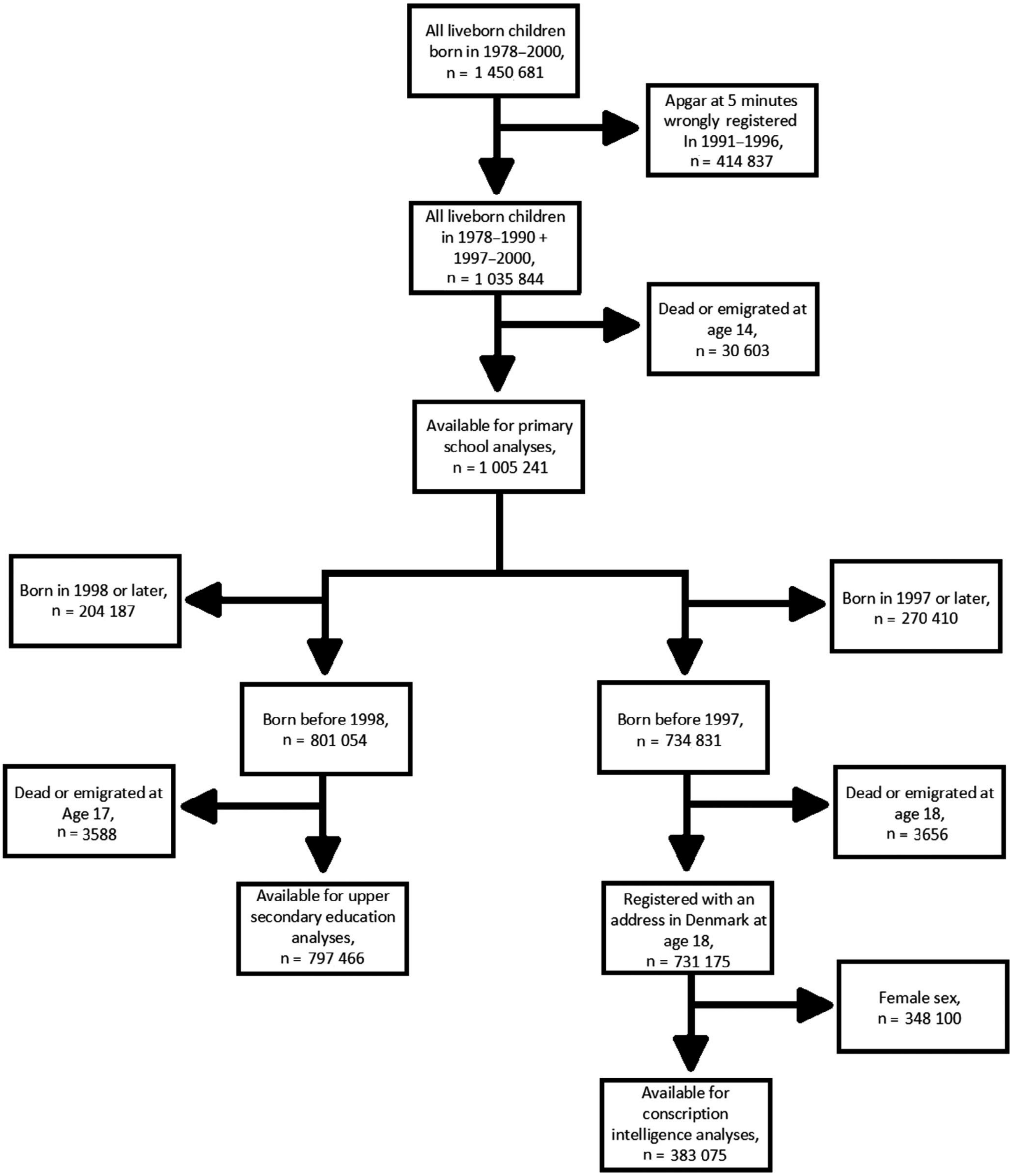

FIGURE 1 Flow chart of the study cohort

2.5 | Statistical analyses

Statistical analyses were performed using R-studio. Missing values appeared in the variables AS5, gestational age, ethnicity, birthweight, parity and marital status of the mother, and educational level of the parents. The amount of missing data was between 0.12% and 6.45% except for parity of the mother which had 22.89% missing data. We performed multiple imputations using the package MICE to avoid discarding data. For all missing values, 10 imputations of five iterations each were done.

We performed univariate and multivariate logistic and linear regressions and the results are presented as odds ratio (OR) or regression coefficients with 95% confidence intervals (CI). We performed post hoc analyses with data stratified on term and preterm birth.

2.6 | Ethical approval

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 1 005 241 liveborn children and contained 927 (0.09%) children born with an AS5 of 0–3, 4986 (0.5%) children born with a score between 4 and 6 and 983 481 (98%) children born with a score of 7 or more. A total of 15 847 (1.6%) children were not registered with an AS5. Characteristics of the cohort are listed in Table 1. Almost half of the children in the 0–3 group were dead or emigrated at age 14 compared with considerably lower proportions in the 4–6 and 7–10 groups. The 0–3 group had the highest proportion of maternal chronic disease and breech presentation. The proportion of primiparous women and multiple pregnancies was higher in the 0–3 and 4–6 groups than in the 7–10 group.

Both mean gestational age and mean birthweight were lowest in the 0–3 group and highest in the 7–10 group. The proportion of ethnic Danish children was similar in the groups.

The observed results for educational outcome are listed in Table 2. Overall, the AS5 0–3 and 4–6 groups received slightly lower average PS grades compared with the 7–10 group, but the differences for total grades and the grades of specific subjects were all within 0.1–0.3 grades.

For USE, the proportion of graduated children was lowest in the 0–3 group and highest in the 7–10 group ($p = <0.001$). None of the USE grades were significantly different.

Table 3 shows a logistic model of the association between AS5 and graduating PS and USE. In the adjusted analyses there were no significant differences regarding PS. For USE, the OR of graduating significantly increased with increasing AS5 in both unadjusted and adjusted analyses.

Table 4 shows a linear model of the association between AS5 and school grades. For PS, the total mean average and the core subject mean average were significantly lower for the 4–6 group than for the 7–10 group (reference) in both the unadjusted and adjusted models. For the 0–3 group there were no significant differences from the reference group. For USE there were no significant differences in total mean averages.

Table 2 shows intelligence outcomes. The percentage of male children who met before the conscription board was lowest for the 0–3 group and highest for the 7–10 group. The mean intelligence score increased with increasing AS5. Table 3 shows a logistic model of the association between AS5 and attending conscription. In the unadjusted model, there were significantly increasing OR of attending conscription with increasing AS5. In the adjusted model the results were still significant, but the OR were comparable for the 0–3 and the 4–6 groups.

Table 4 shows a linear model of the association between AS5 and mean BPP intelligence scores. In the unadjusted model both the 0–3 and the 4–6 groups had significantly lower mean scores than the 7–10 group. In the adjusted model, only the 4–6 group had significantly lower mean average intelligence scores than the reference group.

The post hoc stratified analyses did not reveal signs of differences between children born preterm and term (Table S3–S5).

4 | DISCUSSION

Our results showed that the 7–10 group had the best outcomes considering graduating USE and attending conscription. The 7–10 group also received slightly higher mean grades in PS. There were no significant differences in the USE grades. The 7–10 group received the highest mean average intelligence scores, but in the adjusted model the differences were only significant compared with the 4–6 group. Though the 7–10 group had the best results, the differences between the groups were small and no dose–response association between AS5 and later cognitive function was seen. The 0–3 group seemed to have results at least as good as those of the 4–6 group concerning grades and intelligence scores. This pattern was most likely a result of selection bias; In the 0–3 group almost half of the children were dead or emigrated at age 14, suggesting that the weakest children from the 0–3 group never reached PS, USE, and conscription. The children from the 0–3 group who grew up however did not have lower cognitive function than children in the 4–6 group and the difference from the 7–10 group was small.

The Apgar score is a clinical score, but a low score will often be associated with congenital malformations, intrauterine disease, eg intrauterine infection, or delivery complications. Whether these are recognized or not, numerous such conditions could be thought to cause neurologic damage and thereby lower cognitive function. This could potentially explain the possible, but weak, association between AS5 and cognitive function in our study. On the other hand, the Apgar score represents a single point in time and does not include resuscitative interventions and response to these. Therefore, the Apgar score will only predict the later cognitive function to a limited extent.

Other studies have found an association between low AS5 and later lower educational outcomes or intelligence. Among young draft-liable men an association between low Apgar scores and later low cognitive function was found.[6] As a result of differences in the modeling of the Apgar score, it is difficult to compare the results directly with ours. Tweed et al. found a dose–response relation between Apgar score and needs for additional support. No association between Apgar score and highest educational attainment was

TABLE 1 Characteristics of pregnant women and their children born in Denmark in 1978–1990 and 1997–2000[a]

Characteristics	Apgar score at 5 min: 0–3	Apgar score at 5 min: 4–6	Apgar score at 5 min: 7–10	Missing
Number (%) (*N* = 1 005 241)	927 (0.092)	4986 (0.50)	983 481 (98)	15 847 (1.58)
Sex, *n* (%)				0 (0)
Male	521 (56)	2849 (57)	513 688 (52)	
Female	406 (44)	2137 (43)	469 793 (48)	
Ethnicity, *n* (%)				1159 (0.12)
Danish	866 (93)	4762 (95)	937 745 (95)	
Second-generation immigrant	57 (6)	217 (4)	44 614 (5)	
Parents living together, *n* (%)				2392 (0.24)
Together	734 (79)	3894 (78)	801 520 (82)	
Apart	190 (20)	1082 (22)	1 850 304 (18)	
Paternal education, *n* (%)				33 033 (3.29)
Very short	1712 (77)	3918 (79)	746 936 (76)	
Short	30 (3)	136 (3)	32 074 (3)	
Medium	90 (10)	465 (9)	106 095 (11)	
Long	51 (6)	285 (6)	66 629 (7)	
Maternal education, *n* (%)				18 723 (0.19)
Very short	708 (76)	3852 (77)	730 338 (74)	
Short	22 (2)	158 (3)	31 098 (3)	
Medium	148 (16)	741 (15)	170 119 (17)	
Long	29 (3)	144 (3)	34 332 (4)	
Mean mother's age, years (SD)[b]	27.80 (5.11)	27.56 (5.17)	27.61(4.88)	0 (0)
Maternal chronic disease, *n* (%)				0 (0)
Yes	74 (8)	332 (7)	44 846 (5)	
No	853 (91)	4654 (93)	938 635 (95)	
Maternal parity, *n* (%)				230 138 (22.89)
Primipara	450 (49)	2424 (49)	373 381 (38)	
Multipara	321 (35)	1544 (31)	385 026 (39)	
Delivery complications, *n* (%)				0 (0)
Yes	65 (7)	400 (8)	33 164 (4)	
No	862 (93)	4586 (92)	950 317 (96)	
Mode of delivery, *n* (%)				0 (0)
Vaginal	602 (65)	3138 (63)	848 862 (86)	
Cesarean section	325 (35)	1848 (37)	134 619 (14)	
Interventions during delivery, *n* (%)				0 (0)
Yes	137 (10)	1070 (22)	89 373 (9)	
No	790 (90)	3914 (78)	849 108 (91)	
Breech presentation, *n* (%)				0 (0)
Yes	122 (13)	554 (11)	42 616 (4)	
No	805 (87)	4434 (89)	940 865 (96)	
Mean gestational age, weeks (SD)	37.43 (4.32)	38.07 (3.77)	39.59 (1.79)	64 828 (6.45)
Mean birthweight, gram (SD)	2895 (1002)	3022 (903)	3423 (572)	8553 (0.85)
Multiple pregnancy, *n* (%)				0 (0)
Yes	69 (7)	327 (7)	24 156 (2)	
No	858 (93)	8659 (93)	959 325 (98)	

TABLE 1 (Continued)

Characteristics	Apgar score at 5 min: 0–3	Apgar score at 5 min: 4–6	Apgar score at 5 min: 7–10	Missing
Dead or emigrated, *n* (%)				0 (0)
At age 17	4 (0.4)	34 (0.7)	4509 (0.5)	
At age 18	5 (0.5)	44 (10.8)	4551 (0.5)	

[a]Observed data.
[b]SD, standard deviation.

TABLE 2 Educational and intelligence outcomes[a]

Variable	Apgar score at 5 min: 0–3	Apgar score at 5 min: 4–6	Apgar score at 5 min: 7–10	*p* value	Missing, *n* (%)
Primary school, *n* (%) (*N* = 1.005.241)	927 (0.1)	4986 (0.5)	983 481 (98)	—	15 847 (2)
Graduated primary school, *n* (%)				< 0.001	0 (0)
Yes	864 (93)	4660 (93)	936 752 (95)		
No	63 (7)	326 (7)	46.729 (5)		
Registered with at least four grades, *n* (%)				0.006	0 (0)
Yes	489 (53)	2.448 (49)	504 266 (51)		
No	483 (47)	2538 (51)	479 215 (49)		
Total grade average, mean (SD)[b]	6.3 (2.4)	6.3 (2.2)	6.5 (2.2)	< 0.001	489 229 (49)
English grade average, mean (SD)	6.4 (3.2)	6.5 (3.0)	6.7 (3.0)	< 0.001	489 220 (49)
Danish grade, mean (SD)	6.3 (2.4)	6.3 (2.3)	6.5 (2.3)	< 0.001	489 220 (49)
Mathematic grades average, mean (SD)	6.3 (2.8)	6.2 (2.7)	6.4 (2.6)	0.0043	489 220 (49)
Core subjects grade average, mean (SD)	6.4 (2.5)	6.3 (2.4)	6.6 (2.4)	< 0.001	489 220 (49)
Upper secondary education, *n* (%) (*N* = 797 466)	733 (0.1)	3901 (0.5)	782 243 (98)	—	10 589 (1)
Graduated upper secondary education, *n* (%)				< 0.001	0 (0)
Yes	320 (44)	1763 (45)	410 990 (53)		
No	413 (56)	2138 (55)	371 253 (47)		
Registered with at least four grades, *n* (%)				< 0.001	0 (0)
Yes	302 (41)	1626 (42)	374 632 (48)		
No	431 (59)	2275 (58)	407 611 (52)		
Total grade average, mean (SD)	6.4 (2.1)	6.4 (2.0)	6.5 (2.9)	0.23	416 301 (52)
English grade average, mean (SD)	6.3 (2.7)	6.2 (2.6)	6.3 (2.6)	0.20	416 599 (52)
Danish grade average, mean (SD)	6.3 (2.4)	6.2 (2.4)	6.4 (2.3)	0.030	416 571 (52)
Mathematics grade average, mean (SD)	5.7 (3.4)	5.7 (3.3)	5.8 (3.2)	0.25	475 473 (60)
Core subjects grade average, mean (SD)	6.1 (2.4)	6.0 (2.3)	6.2 (2.2)	0.15	475 473 (60)
Conscription, *n* (%) (*N* = 383 075)	368 (0.1)	1995 (0.3)	376 421 (98)	—	4291 (1)
Appearance before conscription board, *n* (%)				<0.001	0 (0)
Yes	224 (61)	1244 (62)	272 445 (72)		
No	144 (39)	751 (38)	103 976 (28)		
Session score, mean (SD)	42.3 (10.1)	42.6 (9.9)	43.7 (9.6=)	<0.001	105 414 (28)

[a]Observed data.
[b]SD, standard deviation.

found, possibly supporting our findings.[9] In contrast to our findings, Odd et al. found a dose–response relation between time to reach Apgar scores of 7 or more and different cognitive scores.[10] Stuart et al. reported lower OR of need for education in special schools among children born with Apgar scores at 0 compared with children with scores of 1–8 supporting our suggestions of a selections bias.[8]

TABLE 3 Logistic model showing the association between Apgar score at 5 minutes and graduating primary and upper secondary school and attending at conscription

OR[a] of graduating education	Apgar score at 5 min: 0–3	95% CI[b]	Apgar score at 5 min: 4–6	95% CI	Apgar score at 5 min: 7–10
Unadjusted primary school	0.66	0.52–0.85	0.71	0.64–0.80	Reference
Adjusted[c] primary school	0.95	0.73–1.24	0.96	0.85–1.1	Reference
Unadjusted upper secondary school	0.69	0.59–0.79	0.74	0.70–0.79	Reference
Adjusted[c] upper secondary school	0.79	0.67–0.93	0.86	0.81–0.93	Reference
Unadjusted conscription	0.60	0.48–0.74	0.63	0.58–0.69	Reference
Adjusted[c] conscription	0.73	0.59–0.91	0.73	0.66–0.80	Reference

[a]OR, odds ratio.

[b]CI, confidence interval.

[c]Adjusted for: sex, gestational age, birthweight, delivery complications, breech presentation, cesarean section, interventions during delivery, congenital malformations, multiple pregnancy, parity of the mother, mother's age at birth, 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 Apgar score at 5 minutes and school grades and conscription intelligence test scores

Educational level	Unadjusted Apgar 0–3	95% CI[b]	Unadjusted Apgar 4–6	95% CI	Unadjusted Apgar 7–10	Adjusted[a] Apgar 0–3	95% CI	Adjusted[a] Apgar 4–6	95% CI	Adjusted[a] Apgar 7–10
Primary school total mean average	−0.14	−0.34 – 0.06	−0.20	−0.29 to −0.11	Reference	−0.039	−0.21 – 0.13	−0.13	−0.21 to −0.054	Reference
Primary school core subject mean average	−0.17	−0.32 – 0.04	−0.22	−0.32 to −0.13	Reference	−0.061	−0.24 – 0.12	−0.15	−0.23 to −0.064	Reference
Upper secondary school total mean average	−0.020	−0.24 – 0.20	−0.082	−0.18 −0.014	Reference	0.056	−0.16 −0.27	−0.034	−0.13 – 0.058	Reference
Børge Prien test score, mean average	−1.37	−2.7 to −0.06	−1.12	−1.66 to −0.59	Reference	−0.29	−1.54 – 0.97	−0.57	−1.09 to −0.058	Reference

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

[b]CI, confidence interval.

Finally, Seidman et al. did not find an association between low Apgar score at 1 and 5 minutes and intelligence at age 17. They only located one individual with an AS5 of 3 or less and this individual had a higher intelligence score than the mean score for the other groups. When looking at Apgar score at 1 minute they found slightly higher mean intelligence scores for the 0–3 group than for the 4–7 and more than 7 groups, which is consistent with our results.[27]

The strengths of our study are mainly the population size with more than one million liveborn children and the amount of available data. Because of the nationwide follow up of all pregnancies, the risk of selection bias is limited,[28] and the prospective nature of data collection in a follow-up design would tend to suggest non-differential misclassification.[29]

The national registries allowed us to look at a wide time span and include relevant, potential confounders in our analyses with a relatively low amount of missing data, allowing little room for residual confounding.[30] Parental educational level has been suggested to be an important confounder for childhood development and performance, but it did not seem to be a strong confounder in our study. A possible explanation could be the well-developed, public and free-of-charge access to antenatal care and birth assistance in Denmark ensuring the same standard for all, independent of educational level and other socio-economic factors. No power calculations were performed, because the study was based on national data across several decades, and hence even small differences of less than <0.2 marks or less than 1 IQ-point would become significant.

The main limitation relates to the skewed distribution of children having died or emigrated before reaching school or conscription, increasing the risk of bias arising from conditioning on being alive and living in Denmark. As a result of this bias, we might have overestimated the cognitive function for children with low AS5, though the magnitude is unknown.

5 | CONCLUSION

Overall, compared with children with AS5 of 7 or more, children born with lower AS5 performed equally well at the end of PS, USE, and (for young men) at the conscription intelligence test. Although the chances of graduating PS were the same, chances of graduating USE and being called to the conscription board were significantly lower in the 0–3 and 4–6 groups compared with the 7–10 group, suggesting that either you fail to appear, or—if you do—you will perform as well as anyone else. This information should be consoling news for parents of children born with low Apgar scores. In a clinical setting this information is easily disseminated.

CONFLICT OF INTEREST

Steen Ladelund is an employee of and holds shares in Novo Nordisk A/S. The other authors declare no conflicts of interests.

AUTHOR CONTRIBUTIONS

AKL conceptualized and designed the study, collected data, carried out analysis and interpretation of data, and drafted the initial manuscript. FJB conceptualized and designed the study and collected data. JAS collected data. SL carried out analysis and interpretation of data. USK conceptualized and designed the study, and interpreted data. All authors reviewed and revised the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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