Five minute Apgar score and educational outcomes: retrospective cohort study of 751,369 children

Short title: Apgar score and educational outcomes

Emily J Tweed[1], MB ChB; Daniel F Mackay[1], PhD; Scott M Nelson,[2] PhD; Sally-Ann Cooper, MD;[1] Jill P Pell[1], MD.

1. Institute for Health and Wellbeing, University of Glasgow, Glasgow, G12 8RZ, UK
2. School of Medicine, University of Glasgow, Glasgow, G31 2ER, UK

Corresponding author

Professor Jill Pell (jill.pell@glasgow.ac.uk)
Institute of Health and Wellbeing, University of Glasgow
1 Lilybank Gardens
Glasgow G12 8RZ
Tel: 0141 330 3239

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ABSTRACT

Background

The Apgar score is used worldwide for assessing the clinical condition and short-term prognosis of newborn infants. Evidence for a relationship with long-term educational outcomes is conflicting. We investigated whether Apgar score at five minutes after birth was associated with additional support needs (ASN) and educational attainment.

Methods

Data on pregnancy, delivery and later educational outcomes for children attending Scottish schools between 2006 and 2011 were collated by linking individual-level data from national educational and maternity databases. The relationship between Apgar score and overall ASN, type-specific ASN and educational attainment was assessed using binary, multinomial and generalised ordinal logistic regression models respectively. Missing covariate data were imputed.

Results

Of the 751,369 children eligible, 9,741 (1.3%) had a low or intermediate Apgar score and 49,962 (6.6%) had ASN. Low Apgar score was independently associated with overall ASN status (adjusted odds ratio for Apgar d3, OR 1.52 95% CI 1.35-1.70), as well as ASN due to cognitive (OR 1.26, 95% CI 1.09-1.47), sensory (OR 2.49 95% CI 1.66-3.73) and motor (OR 3.57, 95% CI 2.86-4.47) impairments. There was a dose-response relationship between Apgar score and overall ASN status: of those scoring 0-3, 10.1% had ASN, compared to 9.1% of those scoring 4-7 and 6.6% of those scoring 7-10. A low Apgar was associated with lower educational attainment, but this was not robust to adjustment for confounders.

Conclusions

Apgar scores are associated with long- as well as short-term prognosis, and with educational as well as clinical outcomes at the population level.

INTRODUCTION

Educational experience and attainment in childhood is a key determinant of health across the lifecourse[1]. In Scotland, the education sector has a statutory duty to identify and provide for children with additional support needs (ASN), defined as difficulties in learning requiring different or extra educational support compared to peers of their own age[2, 3].

To date a number of preschool factors, including pre- and perinatal characteristics, have been identified as being associated with subsequent ASN.

The neonatal Apgar score, created by Dr Virginia Apgar in 1952, remains in routine clinical use for determining the need for, and effectiveness of, resuscitation, and as a marker of short-term prognosis[4-6]. Low Apgar scores at birth are also consistently associated with an increased risk of subsequent neurological conditions such as cerebral palsy[7-11], epilepsy[11-14] and cognitive impairment[15, 16]. However, uncertainty remains regarding the long-term relationship between Apgar score, different types of ASN and educational outcomes, particularly in children without other risk factors such as preterm delivery or low birthweight.

We carried out a Scotland-wide retrospective cohort study linking birth and educational records to investigate whether Apgar score at five minutes of age was associated with overall, as well as type-specific, ASN and educational attainment.

METHODS

Data sources

We linked individual-level data on pregnancy, delivery and later educational outcomes from three national databases: the Scottish Morbidity Record 2 (SMR02), and the Scottish school census and school attainment record.

The SMR02 collects data on antenatal factors and delivery outcomes for all women discharged from maternity hospitals in Scotland[17]. Apgar score at five minutes of age was categorised into three ordinal groups; low (0-3), intermediate (4-6) and normal (7-10)[18]. Each child's postcode of residence was used to assign a Scottish Index of Multiple Deprivation (SIMD) score as an area-level proxy for socioeconomic status[19].

The school census covers all children attending local authority maintained and grant-aided primary and secondary schools in Scotland and includes both mainstream and special schools. Pupil-level data, including ASN status, are submitted annually by each school to the Scottish Government Education Analytical Services division (known as ScotXEd). Identification of children with ASN is a statutory duty of schools in Scotland[2, 3].

Educational attainment data were obtained from the Scottish Qualifications Authority (SQA), which maintains a database of all children who have been entered for a qualification and the result attained. Using the SQA's established Unified Points Scale, which summates tariff points assigned to each examination result based on the level of qualification and the grade achieved, pupils at different educational stages are stratified into the categories of low, basic, high and very high attainment. Since only a proportion of children included in the school

census data had reached the stages at which summative qualifications are undertaken, analysis of educational attainment was carried out on this subgroup only.

NHS Information Services Division Scotland (ISD) used probabilistic matching to link records from SMR02 and the education sector. Pupils included in the school census (identified by a Scottish Candidate Number, a unique identifier from the education sector) were matched using date of birth, gender and postcode of residence with the Community Health Index (CHI) database to identify each pupil's CHI number, a unique identifier allocated to all patients registered with a family doctor in Scotland. This CHI number was then linked to the maternal record in the SMR02 database via statutory birth registration records containing both child and maternal CHI number. SCN numbers were used to link pupils from the school census to educational attainment data from the SQA. This method has been previously described[20]: a detailed description of the matching algorithm is provided in Appendix 1.

The work was enabled by data sharing agreements between the University of Glasgow and ScotXEd, SQA and ISD. Approvals were also obtained from ISD's Privacy Advisory Committee and from the Community Health Index Advisory Group. NHS West of Scotland Research Ethics Service confirmed that NHS ethical approval was not required for this study.

Inclusion criteria and definitions

School census data were collected on all children attending Scottish schools between the academic years 2006/7 and 2011/12 inclusive. Our analyses were limited to singleton births with birthweight 400-6,500g and estimated gestational age at delivery of 37-43 weeks to women of any parity over ten years of age and 100-200cm in height. Infants for whom five-

minute Apgar score was not recorded were excluded. Multiple pregnancies were excluded because it was impossible to determine birth order in the linked dataset and hence attribute variables such as Apgar score to the correct sibling.

Five-minute Apgar score was categorised into three ordinal groups; low (0-3), intermediate (4-6) and normal (7-10)[18]. The definition of ASN used in this analysis did not include social, cultural, linguistic, or emotional factors (for example, bereavement or English as a second language) unlikely to be related to perinatal events and Apgar scores at birth. The category of 'mental health problems' contained too few individuals for meaningful sub-group analysis so was also excluded from the definition of ASN. Thus, the five categories of ASN included in the analysis were: cognitive (intellectual disability, other learning disability, or dyslexia), visual and/or hearing impairment (visual impairment, hearing impairment or deaf/blindness), physical and/or motor disability (physical or motor impairment, or physical health problem), language or speech disorder, and autism spectrum disorder. Pupils were identified as having ASN if their school census record for any year contained a flag for ASN. Categories were mutually exclusive: children with more than one type of ASN were classified according to their main impairment.

Statistical analyses

All analyses were undertaken using Stata v12.1. Groups were compared using chi-squared, Kruskal-Wallis and Spearman rank correlation tests for categorical, continuous and ordinal data respectively. Statistical significance was assumed at $p<0.05$. Binary, multinomial and generalised ordinal logistic regression models were used for the outcomes of overall ASN status, type-specific ASN and educational attainment respectively. Multivariable models were

used to adjust for potential confounders: sex; maternal age, height and smoking; parity; marital status; socioeconomic deprivation; presentation; mode of delivery; gestational age and sex-, gestation-specific birthweight centile. Population attributable fraction was calculated using the aflogit function in Stata, after adjusting for the covariates listed above. For educational attainment, we tested first for a univariate association with ASN and then constructed multivariable models containing an interaction between Apgar score and ASN or ASN as a stand-alone covariate.

In the multivariable models, missing values for maternal height and smoking status were imputed using the ICE function in Stata, with the creation of five imputed datasets. Complete data are shown in supplementary tables 5, 6 and 7.

RESULTS

Of the 1,011,585 children included in the school censuses conducted between 2006 and 2011 inclusive, 811,860 (80.3%) could be linked to delivery data. Of these, 60,491 (7.5%) were excluded, for the following reasons: multiple pregnancy (n=8,585), gestational age (n=45,957), birthweight (n=348), maternal age or height (n=164) and missing Apgar score (n=5,437). The study population comprised the remaining 751,369 children. Of these, 331,394 (44.1%) had undertaken summative examinations with the SQA and could be included in analyses of educational attainment. Year of birth ranged from 1989 to 2006, with 464,182 children (61.8%) born before 2000 and 287,186 (38.2%) born during or after 2000. The mean age of children included was 12.6 years (SD=3.8). Figure 1 shows a flow chart of the study cohort.

Overall, 741,628 (98.7%) children had an Apgar score of 7-10, 6,393 (0.9%) had a score of 4-6 and 3,348 (0.4%) had a score of 0-3; 49,962 (6.6%) children had a record of ASN (Table 1). Of these 49,962 children: 33,031 (66.1%) had cognitive impairment; 5,330 (10.7%) had physical or motor impairments; 4,986 (10.0%) had autistic spectrum disorder; 4,401 (8.8%) had language or speech problems; and 2,214 (4.4%) had visual or hearing impairments.

Children with Apgar scores <7 were more likely to be male, breech presentation, of lower socioeconomic quintile, gestational age and sex- and gestation-specific birthweight, and to be born by emergency caesarean section or to multiparous mothers. They were also more likely to have ASN: 921 (9.5%) children with an Apgar <7 required ASN during their subsequent schooling in comparison to 49,041 (6.6%) of those with an Apgar of e7 ($p < 0.001$). The association between low Apgar score and subsequent ASN was robust to adjustment for confounding factors and there was a dose-response relationship across the three Apgar score groups (Table 2). The population attributable fraction for Apgar score <7 in relation to ASN after adjustment for confounding factors was 0.49% (95% CI 0.37-0.62%).

With regard to specific causes of ASN, Apgar scores less than 7 were independently associated in a dose-response manner with physical/motor, visual/hearing and cognitive disorders, though not with autistic spectrum disorders (Table 3). Multivariable analyses also identified an association between risk of language/speech disorders and Apgar score of 4-6, but this was not statistically significant at lower Apgar scores.

Among those children who had sat external examinations, low Apgar score was associated with lower educational attainment in univariate analysis, but the association became non-significant when adjusted for potential confounding factors (Table 4). ASN was strongly

associated with reduced likelihood of high educational attainment (univariate OR 0.22, 95% CI 0.22-0.23). However, adjustment for ASN did not change the association between low Apgar and educational attainment, nor was there a significant interaction between Apgar score and ASN.

DISCUSSION

A five-minute Apgar score of less than seven was a significant risk factor for ASN at school even after adjusting for potential confounders. The association was strongest for ASN resulting from physical and motor impairments, followed by visual, hearing and cognitive impairments. There was no association with autistic spectrum disorders.

The association between suboptimal Apgar score and lower educational attainment was not robust to adjustment for potential confounders and was unaffected by ASN status, despite any ASN requirement greatly reducing the odds of reaching the highest levels of educational attainment. This may reflect the low proportion of children with low Apgar scores among the subgroup of children with ASN, reflected in the low PAF.

Previous studies on the association between Apgar score and ASN have reported conflicting results. Some have found no association but had methodological limitations, such as small sample sizes[21, 22], parental-reported outcomes[22] and selection bias[23]. In contrast, a number of larger and more robust studies have demonstrated increased risk of learning disability[24] or special educational needs schooling[14, 25-27] among children with low Apgar scores at birth. These include a Norwegian birth cohort where children with a low Apgar score were more likely to have ASN and below-average educational performance, as

reported by parents[14]; three large linkage studies from the US in which low Apgar score predicted later school-age ASN or learning disability[24-26]; and a Swedish linkage study in which lack of graduation grades was used as a proxy for attendance at a special school[27]. Another linkage study of Swedish boys reported that low Apgar scores, in the absence of overt encephalopathy, were associated with poorer results on cognitive testing but not school grades[15], which fits with our finding of no relationship between Apgar score and subsequent educational achievement.

Our finding that low Apgar scores at five minutes after birth were significantly associated only with certain types of ASN is plausible given existing evidence. Previous studies have demonstrated poorer cognitive outcomes[15, 16] among children with low Apgar scores at birth. The association between low Apgar scores and physical/motor causes of ASN may partly reflect the established association with disorders such as cerebral palsy[7-11]. Low Apgar score is also a well-recognised risk factor for sensorineural hearing loss[28-31]. Evidence has previously been lacking on whether low Apgar score is associated with visual impairment in children born at term without encephalopathy[32], whilst previous studies have produced conflicting results as to whether low Apgar score is associated with speech and language difficulties[33, 34] or autistic spectrum disorders[35].

The study described here has a number of strengths compared to the existing literature on this topic. It is based on a large nationwide cohort of more than 700,000 children, for whom data on ASN and educational performance were collected as a statutory requirement. All eligible children attending mainstream or special schools in Scotland during the study period were included, to enhance generalisability. Unlike previous studies, our analysis looks not only at the association of Apgar scores with overall ASN status but at a comprehensive range of

specific ASN types. We were able to obtain individual-level data on the relationship between Apgar scores and ASN over a long period of follow-up, and to adjust for a number of important potential confounders. Use of quality-assured routine data sources and a high level of completeness of Apgar score data also engender confidence in our results. Finally, the recency of these data is an important strength, given advances in neonatal resuscitation since many previous studies in this field were carried out.

The majority of pupils could be linked to delivery data: those that could not are likely to have been born outside of Scotland. The study population will not include those children born in Scotland who emigrated or died prior to entering the school system, an unavoidable limitation of the routine data sources.

Another potential limitation lies in the accuracy of assessment of Apgar scores: previous studies have suggested significant inter- and intra-observer variability in scoring, particularly among pre-term infants and those receiving resuscitation[36, 37]. While we were unable to assess the accuracy of scoring or the extent of resuscitation provided, this study aimed to minimise the impact of these factors by excluding pre-term infants and using the 5 minute Apgar score to incorporate the effect of any immediate resuscitative measures. Furthermore, any measurement error in Apgar score might be expected to bias towards the null, potentially under-estimating the association between Apgar score and ASN. Though modifications to the Apgar score have been proposed to address these shortcomings[38], these are not yet in widespread clinical use.

Data were not available on adverse antenatal or intra-partum events, neonatal encephalopathy or childhood health problems, which might offer a causal explanation for the association

observed. We also excluded multiple pregnancies, preterm deliveries and very low birth weight infants, so results may not be generalizable to children with these characteristics.

The relationship seen here between Apgar score and ASN does not necessarily imply causality: Apgar score is therefore best characterised as a risk marker for adverse later life outcomes, rather than a causal factor. Furthermore, the population attributable fraction estimate for low Apgar score suggests that this exposure is unlikely to be a major contributor to the population burden of ASN. Nonetheless, our findings are important because they suggest that it may be possible in the future to identify specific modifiable factors in the perinatal period that could improve children's outcome in the long term.

Conclusion

This study has demonstrated a strong and dose-dependent association between low Apgar score at five minutes after birth and later ASN, independent of key confounding variables, and has further investigated this relationship by the type of ASN. Apgar scores are therefore associated with long- as well as short-term prognosis and with educational as well as clinical outcomes at the population level.

WHAT IS ALREADY KNOWN ON THIS TOPIC?

- Neonatal Apgar score is known to predict short- and long-term survival and neurological outcomes.
- Whether a low Apgar score is associated with an overall requirement for additional support needs (ASN), different ASN subtypes or long-term educational attainment is unknown.

WHAT THIS STUDY ADDS

- Low Apgar score was strongly associated in a dose-dependent manner with need for additional educational support in later life, after adjusting for confounding factors.
- The association was strongest for additional support needs resulting from physical and motor impairments, followed by visual, hearing and cognitive impairments.
- Low Apgar score was also associated with lower educational attainment, but this was not robust to adjustment for confounders.

ADDITIONAL INFORMATION

Contributorship:

Emily J. Tweed: conceptualised and designed the study, carried out data analyses, contributed to data interpretation, drafted the initial manuscript, revised the manuscript, and approved the final manuscript as submitted.

Daniel F. Mackay: conceptualised and designed the study, obtained the data, carried out data analyses, contributed to data interpretation, revised the manuscript and approved the final manuscript as submitted.

Scott M. Nelson: contributed to data interpretation, revised the manuscript and approved the final manuscript as submitted.

Sally-Ann Cooper: contributed to data interpretation, revised the manuscript and approved the final manuscript as submitted.

Jill P. Pell: conceptualised and designed the study, obtained the data, contributed to data interpretation, revised the manuscript and approved the final manuscript as submitted.

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LICENCE STATEMENT

Table 1. Characteristics and educational outcomes of children attending Scottish schools between 2006 and 2011, by five minute Apgar score.

		0-3	4-6	7-10	P value[1]
		n=3,348	n=6,393	n=741,628	
		Median (IQR)	Median (IQR)	Median (IQR)	
Maternal age (years)		28 (8)	27 (9)	28 (8)	<0.001
		n (%)	n (%)	n (%)	
Infant sex	Male	1,676 (50.1)	3,598 (56.3)	377,726 (50.9)	<0.001
	Female	1,672 (49.9)	2,795 (43.7)	363,902 (49.1)	
Marital status of mother	Married	1,953 (59.9)	3,455 (56.0)	418,081 (58.4)	<0.001
	Not married	1,310 (40.1)	2,713 (44.0)	297,850 (41.6)	
	Missing	85	225	25,697	
Parity	Multiparous	2,018 (60.4)	2,810 (44.1)	408,364 (55.3)	<0.001
	Nulliparous	1,325 (39.6)	3,560 (55.9)	330,187 (44.7)	
	Missing	5	23	3,077	
Maternal smoking in pregnancy	No	2,011 (73.1)	3,911 (72.6)	469,569 (74.3)	0.008
	Yes	739 (26.9)	1,477 (27.4)	162,798 (25.7)	
	Missing	598	1,005	109,261	
SIMD quintile	1 (most deprived)	967 (29.1)	1,794 (28.2)	195,674 (26.5)	<0.001
	2	720 (21.6)	1,361 (21.4)	153,555 (20.8)	
	3	562 (16.9)	1,262 (19.8)	136,815 (18.5)	
	4	557 (16.7)	1,031 (16.2)	129,380 (17.5)	
	5 (least deprived)	523 (15.7)	926 (14.5)	123,771 (16.7)	
	Missing	19	19	2,433	
Presentation	Cephalic	2,952 (88.2)	5,940 (92.9)	702,117 (94.7)	<0.001
	Breech	396 (11.8)	453 (7.1)	39,507 (5.3)	

	Missing	0	0	4	
Mode of delivery	Vaginal	2,328 (69.5)	3,727 (58.3)	520,207 (70.1)	<0.001
	Vaginal assisted	300 (9.0)	754 (11.8)	80,885 (10.9)	
	Caesarean section	683 (20.4)	1,822 (28.5)	130,523 (17.6)	
	Other/missing	37 (1.1)	90 (1.4)	10,013 (1.4)	
Gestation at delivery (weeks)	37	236 (7.1)	478 (7.5)	37,565 (5.1)	<0.001
	38	499 (14.9)	806 (12.6)	98,060 (13.2)	
	39	720 (21.5)	1,135 (17.8)	159,526 (21.5)	
	40	1,138 (34.0)	1,969 (30.8)	241,889 (32.6)	
	41	618 (18.5)	1,643 (25.7)	172,512 (23.3)	
	42	133 (4.0)	356 (5.6)	31,213 (4.2)	
	43	4 (0.1)	6 (0.1)	863 (0.1)	
Overall ASN status	No	3,010 (89.9)	5,810 (90.9)	692,587 (93.4)	<0.001
	Yes	338 (10.1)	583 (9.1)	49,041 (6.6)	
Type-specific ASN	No ASN	3,010 (89.9)	5,810 (90.9)	692,587 (93.4)	<0.001
	Cognitive	188 (5.6)	342 (5.4)	32,501 (4.4)	
	Visual/hearing	24 (0.7)	33 (0.5)	2,157 (0.3)	
	Physical/motor	80 (2.4)	100 (1.6)	5,150 (0.7)	
	Language/speech	24 (0.7)	64 (1.0)	4,313 (0.6)	
	Autistic spectrum	22 (0.7)	44 (0.7)	4,920 (0.7)	
Educational attainment	Low	150 (7.5)	210 (7.1)	22,549 (6.9)	<0.001
	Basic	810 (40.6)	1,178 (39.6)	122,840 (37.6)	
	Broad general	462 (23.2)	709 (23.8)	79,350 (24.3)	
	High	571 (28.7)	878 (29.5)	101,675 (31.2)	
	Missing	1,355	3,418	415,214	

ASN, additional support needs; CS, caesarean section; IQR, interquartile range; n, number; SIMD, Scottish Index of Multiple Deprivation

1. Kruskal-Wallis test for maternal age; Chi-squared test for infant sex, presentation, urgency, mode of delivery, gestation at delivery, birthweight centiles, overall ASN status, type-specific ASN; and Spearman's rank correlation test for SIMD quintile and educational attainment.

Table 2. Univariate and multivariable binary logistic regression analysis of the association between five minute Apgar score and overall additional support needs status.

		Univariate			Multivariable[2]		
		OR	95% CI	P value	OR	95% CI	P value
Apgar score	0-3	1.59	1.42-1.78	<0.001	1.52	1.35-1.70	<0.001
	4-6	1.42	1.30-1.54	<0.001	1.34	1.22-1.46	<0.001
	7-10	1.00			1.00		

CI, confidence interval; OR, odds ratio.

2. Adjusted for sex, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile, with multiple imputation for missing values in maternal height and smoking in pregnancy.

Table 3. Univariate and multivariable multinomial logistic regression analysis of the association between five minute Apgar score and type-specific additional support needs.

		Cognitive			Visual/hearing			Physical/motor		
		OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Univariate										
Apgar score	0-3	1.33	1.15-1.54	<0.001	2.56	1.71-3.83	<0.001	3.57	2.86-4.47	<0.001
	4-6	1.25	1.12-1.40	<0.001	1.82	1.29-2.57	0.001	2.31	1.90-2.83	<0.001
	7-10	1.00			1.00			1.00		
Multivariable[3]										
Apgar score	0-3	1.26	1.09-1.47	0.002	2.49	1.66-3.73	<0.001	3.32	2.64-4.18	<0.001
	4-6	1.21	1.09-1.35	0.001	1.71	1.20-2.42	0.003	2.15	1.75-2.63	<0.001
	7-10	1.00			1.00			1.00		

		Language/speech			Autistic spectrum		
		OR	95% CI	P value	OR	95% CI	P value
Univariate							
Apgar score	0-3	1.28	0.86-1.92	0.229	1.03	0.68-1.57	0.894
	4-6	1.77	1.38-2.27	<0.001	1.07	0.79-1.44	0.674
	7-10	1.00			1.00		
Multivariable[3]							
Apgar score	0-3	1.21	0.79-1.84	0.378	1.04	0.67-1.60	0.868
	4-6	1.60	1.23-2.08	<0.001	1.00	0.74-1.35	0.998
	7-10	1.00			1.00		

CI, confidence interval; OR, odds ratio.

3. Adjusted for sex, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile, with multiple imputation for missing values in maternal height and smoking in pregnancy.

Table 4. Univariate and multivariable generalized ordinal logistic regression analysis of the association between five minute Apgar score and highest educational attainment[4]

		Univariate			Multivariable[5] (excluding ASN)			Multivariable[6] (including ASN)		
		OR	95% CI	P value	OR	95% CI	P value	OR	95% CI	P value
Apgar score	0-3	0.88	0.81-0.95	0.001	0.94	0.86-1.02	0.115	0.94	0.87-1.03	0.178
	4-6	0.93	0.87-0.99	0.024	0.97	0.90-1.04	0.340	0.98	0.91-1.05	0.525
	7-10	1.00			1.00			1.00		

ASN, additional support needs; CI, confidence interval; OR, odds ratio.

4. Comparison of low, basic or broad general educational attainment. As the parallel lines assumption is satisfied, results are the same for all categories in generalised ordinal logistic regression analyses.
5. Adjusted for sex, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile, with multiple imputation for missing values in maternal height and smoking in pregnancy.
6. Adjusted for sex, overall ASN status, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile, with multiple imputation for missing values in maternal height and smoking in pregnancy.

Supplementary Table 1**.** Univariate and multivariable binary logistic regression analysis of the association between five minute Apgar score and any additional support needs.

		Univariate n=751,369			Multivariable[1] n=509,206		
		OR	95% CI	*P* value	OR	95% CI	*P* value
Apgar score	0-3	1.59	1.42, 1.78	<0.001	1.53	1.34, 1.75	<0.001
	4-6	1.42	1.30, 1.54	<0.001	1.30	1.18, 1.44	<0.001
	7-10	1.00	-	-	1.00	-	-

CI, confidence interval; OR, odds ratio.

1. Adjusted for sex, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile.

Supplementary Table 2**.** Univariate and multivariable multinomial logistic regression analysis of the association between five minute Apgar score and type-specific additional support needs.

		Cognitive			Visual/hearing			Physical/motor		
		OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Univariate n=751,369										
Apgar score	0-3	1.33	1.15, 1.54	<0.001	2.56	1.71, 3.83	<0.001	3.57	2.86, 4.47	<0.001
	4-6	1.25	1.12, 1.40	<0.001	1.82	1.29, 2.57	0.001	2.31	1.90, 2.83	<0.001
	7-10	1.00	-	-	1.00	-	-	1.00	-	-
Multivariable[2] n=509,206										
Apgar score	0-3	1.34	1.13, 1.59	0.001	2.53	1.59, 4.04	<0.001	3.31	2.52, 4.33	<0.001
	4-6	1.14	1.00, 1.30	0.053	1.65	1.10, 2.48	0.015	2.11	1.67, 2.67	<0.001
	7-10	1.00	-	-	1.00	-	-	1.00	-	-

		Language/speech			Autistic spectrum		
		OR	95% CI	*P* value	OR	95% CI	*P* value
Univariate n=751,369							
Apgar score	0-3	1.28	0.86, 1.92	0.229	1.03	0.68, 1.57	0.894
	4-6	1.77	1.38, 2.27	<0.001	1.07	0.79, 1.44	0.674
	7-10	1.00	-	-	1.00	-	-
Multivariable[2] n=509,206							
Apgar score	0-3	1.14	0.69, 1.90	0.608	0.79	0.45, 1.40	0.420
	4-6	1.65	1.22, 2.23	0.001	1.11	0.81, 1.54	0.513
	7-10	1.00	-	-	1.00	-	-

CI, confidence interval; OR, odds ratio.

2. Multivariable logistic regression adjusted for sex, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile.

Supplementary Table 3. Univariate and multivariable generalized ordinal logistic regression analysis of the association between five minute Apgar score and highest educational attainment[3].

		Univariate n=331,382			Multivariable[4] (excluding ASN) n=205,213			Multivariable[5] (including ASN) n=205,213		
		OR	95% CI	*P* value	OR	95% CI	*P* value	OR	95% CI	*P* value
Apgar score	0-3	0.88	0.81, 0.95	0.001	0.98	0.88, 1.09	0.721	0.99	0.90, 1.10	0.921
	4-6	0.93	0.87, 0.99	0.024	0.99	0.91, 1.08	0.888	1.00	0.92, 1.09	0.996
	7-10	1.00	-	-	1.00	-	-	1.00	-	-

ASN, additional support needs; CI, confidence interval; OR, odds ratio.

3. Comparison of low, basic or broad general educational attainment. As the parallel lines assumption is satisfied, results are the same for all categories in generalised ordinal logistic regression analyses.
4. Adjusted for sex, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile.
5. Adjusted for sex, ASN status, maternal age, maternal height, parity, marital status and smoking in pregnancy, deprivation, presentation, mode of delivery, gestation at delivery and birthweight centile.