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ORIGINAL ARTICLE

Academic achievement at ages 11 and 16 in children born with congenital anomalies in England: A multi-registry linked cohort study

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Abstract

Background: Children born with major congenital anomalies (CAs) have lower academic achievement compared with their peers, but the existing evidence is restricted to a number of specific CAs.

Objectives: To investigate academic outcomes at ages 11 and 16 in children with major isolated structural CAs and children with Down or Turner syndromes.

Methods: This population-based cohort study linked data on approximately 11,000 school-aged children born with major CAs in 1994–2004 registered by four regional CA registries in England with education data from the National Pupil Database (NPD). The comparison group was a random sample of children without major CAs from the background population recorded in the NPD that were frequency matched (5:1) to children with CAs by birth year, sex and geographical area.

Results: Overall, 71.9%, 73.0% and 80.9% of children with isolated structural CAs achieved the expected attainment level at age 11 compared to 78.3%, 80.6% and 86.7% of the comparison group in English language, Mathematics and Science, respectively. Children with nervous system CAs as a whole had the lowest proportion who achieved the expected attainment at age 11. At age 16, 46.9% of children with CAs achieved the expected level compared to 52.5% of their peers. Major CAs were associated with being up to 9% (95% confidence interval [CI] 8%, 11%) and 12% (95% CI 9%, 14%) less likely to achieve expected levels at ages 11 and 16, respectively, after adjustment for socioeconomic deprivation.

Conclusions: Although many children with isolated CAs achieved the expected academic level at ages 11 and 16, they were at higher risk of underachievement compared to their peers. These stark yet cautiously encouraging results are important for counselling parents of children with specific CAs and also highlight the possible need for special education support to reduce potential academic difficulties.

KEYWORDS
academic performance, birth defects, school-aged children, special education

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1 | BACKGROUND

Survival beyond infancy is improving for many children born with congenital anomalies (CAs)[1–5] due to advances in neonatal care and surgical interventions, resulting in an increasing number of children reaching school age. While the association between some chromosomal/genetic syndromes (e.g. trisomy 21, Williams, Fragile X and Prader-Willi syndromes, sex chromosome aneuploidies) and learning difficulties is well described, there is relatively sparse population-based evidence for children born with non-syndromic structural CAs. A recent systematic review reported that children with some non-syndromic CAs were at a higher risk of lower academic achievement than their peers. Academic underperformance is not restricted to children with CAs associated with lower survival (e.g. congenital heart defects [CHDs][6–8]) but also occurs in children with anomalies with higher survival such as isolated orofacial clefts (OFCs).[9–13] More evidence is needed on the educational outcomes of children with other isolated structural CAs, not only to provide positive information to parents about their children's achievements[14] but also to make them aware of potential limitations and the necessity of special support that could assist with the development of their children's academic performance.

This study was undertaken as part of the European collaborative project EUROlinkCAT (https://www.eurolinkcat.eu/) that aimed to investigate the health and educational outcomes of children born with major CAs by linking live births to electronic administrative, health care and education databases. The specific aim of this study was to investigate academic outcomes of children born with selected isolated structural CAs at ages 11 and 16 in state-funded schools using linked education data in the National Pupil Database (NPD).

Synopsis

Study question

What are the academic achievements at ages 11 and 16 in children born with specific structural congenital anomalies (CAs)?

What is already known

There is evidence that some non-syndromic CAs, such as severe congenital heart defects, orofacial clefts and spina bifida, are associated with lower academic achievement, measured using standardised or school tests, in school-aged children.

What the study adds

Data on children from four population-based CA registries linked to national education records in England showed that >70% of children with isolated structural CAs achieved the expected attainment level at 11 years of age. They were 9% and 12% less likely to achieve expected attainment levels at ages 11 and 16, respectively, compared with their peers, although this varied according to type of CA. We present subject-specific attainment levels at ages 11 and 16 for children with over 50 different isolated structural CAs.

2 | METHODS

2.1 | Study design, cohort and inclusion criteria

This study was a population-based retrospective linked cohort study. The cohort included all children with a major CA who were born to mothers resident in areas covered by four English EUROCAT (the European network for the surveillance of CAs)[15–17] registries (East Midlands & South Yorkshire [EMSY], Northern England, Thames Valley and Wessex) and who were alive at the start of school age according to linked civil registrations data (henceforth referred to as EUROCAT children). Included birth years were 1994–2004 for all registries except for EMSY, which began data collection in 1998. A random sample of children from the background population in the NPD, frequency matched to EUROCAT children in a 5:1 ratio by birth year, sex and geographical area, were extracted to serve as a comparison group of peers (henceforth referred to as control children).

Major CAs were classified according to the EUROCAT anomaly subgroups. An isolated CA was defined as a major structural anomaly in one organ system only or as part of a known sequence (e.g. spina bifida with hydrocephalus). We included specific major isolated structural CAs and an overall group of children with any major isolated structural anomaly; in addition, results were presented for three chromosomal CAs (Down, Turner and Klinefelter syndromes) to check that our findings are consistent with existing evidence on the poorer achievements of children with syndromic CAs. In this study, we present results for selected subgroups that had sufficient data to yield interpretable estimates. The corresponding ICD codes and the list of subgroups included are presented in Table S1.

2.2 | Linkage process

The NPD contains detailed individual-level information about pupils in all state-funded schools (including special schools) in England, including test and exam results up to age 18, special education needs and sociodemographic data. The Department for Education (DfE) is the data controller for the NPD. Following approval by the DfE data sharing panel in February 2020, DfE staff performed the linkage between the four CA registries' data and their NPD records using names, date of birth, sex and last known postcode. The extracts containing de-identified NPD data with a generated unique study ID were transferred into the Office for National Statistics (ONS) Secure Research Service (SRS). The same data items were provided for control children. Data on CAs for the EUROCAT children were separately merged with

the NPD data using the study ID within the ONS SRS. The named researchers from St George's, University of London (SGUL), that is, JT, JB, HERE and JKM, were permitted remote access to the linked NPD data in the ONS SRS under an Assured Organisational Connectivity agreement between SGUL and the ONS. JR and SG were permitted access to pre-publication outputs exported from the ONS SRS.

2.3 | Educational outcomes

Key stage 2 (KS2) attainment data from national, externally marked tests were taken at the end of primary school, in year 6 (age 11 for most pupils). Pupils were expected to achieve level 4 by the end of KS2 therefore 'Achieving level 4 and above' by compulsory school subject (English, Mathematics and Science; the latter covers topics within the disciplines of Biology, Chemistry and Physics) was selected as the educational outcome for KS2. The included academic years differed by subject, as only years when the assessments were based on national standardised tests were analysed. For English, included years were 2004/05–2011/12 because from 2012/13, English was calculated from reading test results and writing teacher assessment, making test results incomparable to previous years. For Mathematics, we included years 2004/05–2014/15, as national curriculum levels were replaced by scaled Standard Assessment Test scores in 2015/16. For science, we included 2004/05–2008/09 because from 2009/10, the KS2 national curriculum science test taken by all pupils was replaced by one taken by a sample of pupils only. The classification of subject results codes is given in Table S3.

Key stage 4 (KS4) attainment data were based on national General Certificate of Secondary Education (GCSE) exams and equivalent qualifications at age 16. Results for academic years 2009/10–2015/16 were included as changes in grading were introduced in 2016/17. Level 2 is reached when the pupil has achieved 5 or more GCSEs and equivalents at grades A*-C; we therefore selected Level 2 including GCSE in English and Mathematics as the KS4 educational outcome, since it was used as a secondary schools' performance measure and also deemed to be the foundation for further education or beginning employment.[18]

The requested NPD data also contained an individual-based free school meals eligibility (FSME) based on Spring Census data (collected annually in January). FSME is based on parents receiving certain means-tested benefits, and we used FSME as a single measure of socioeconomic deprivation, a potential confounder of the association between CAs and educational attainment.

2.4 | Statistical analysis

Educational outcomes expressed as KS2 and KS4 attainments were analysed for EUROCAT children from the four English registries combined versus control children. As control children were frequency matched to EUROCAT children by birth year, sex and geographical area, these characteristics, including area-derived socioeconomic deprivation scores (income deprivation affecting children index), were comparable between the two groups. The initially planned 5:1 ratio of control to EUROCAT children was not achieved because of logistical reasons (e.g. no exact matches found, excluded due to data issues/duplicates), resulting in a final overall 4.5:1 ratio.

Generalised linear models with a Poisson distribution, log link and robust standard errors were used to estimate risk ratios (RRs) with 95% confidence intervals (CIs) for achieving expected levels of attainment for EUROCAT children versus control children, without and with adjustment for FSME. To control for differences in academic achievements by sex, the results for boys with hypospadias and Klinefelter syndrome were compared with those for control boys, and the results for girls with Turner syndrome were compared with those for control girls. The ONS SRS statistical disclosure policy does not permit reporting of small counts (<10), including derived quantities which would enable back calculation of small counts (percentages, RRs), and hence suppression had been applied where necessary. Statistical analysis was performed using Stata (version 16.0, StataCorp LP, College Station, TX, USA).

2.5 | Missing data

Approximately, 82% (11,142/13,599) and 80% (5741/7190) of EUROCAT children were linked to KS2 Mathematics (comprising the full 1994–2004 cohort) and KS4 datasets in the NPD, respectively. The primary reason for non-linkage was inadequate matching identifiers collected by registries. A further 3.6% and 5.9% of EUROCAT children had not reached the requisite year group to sit for KS2 Mathematics and KS4 assessments, respectively, in the last year of available data (see Table S2). Overall, 4.9%, 3.1% and 0.1% of children who sat KS2 assessments had missing results for English, Mathematics and Science tests, respectively; for KS4 exam results, there were no missing data. For KS2, there were no missing data for the child's sex, and the percentage of missing data was low for FSME (0.5% EUROCAT; 0.9% and control children). As there were higher percentages of missing data for FSME at KS4 (4.6% EUROCAT; 5.0% control children), we performed sensitivity analysis by sequentially imputing all missing values of FSME as eligible and then ineligible in the adjusted models.

2.6 | Ethics approval

The study had Health Research Authority ethics approval for the linkage between the CA registries' and the NPD records to take place and did not require individual consent (NHS REC reference: 16/EM/0440).

3 | RESULTS

The analysis included up to 10,363 EUROCAT children and 59,090 control children who sat KS2 Mathematics (the maximum cohort). Table 1 shows the number and the percentage of children achieving

TABLE 1 Key stage 2 (KS2) level of attainment in national curriculum tests: number and percentage of children achieving level 4 and above (expected level) for EUROCAT children (children born with congenital anomalies: all anomalies, selected isolated anomalies and chromosomal syndromes) and the comparison group (controls) by school subject.

	English language (2004/05–2011/12)[a]			Mathematics (2004/05–2014/15)[a]			Science (2004/05–2008/09)[a]		
		Achieved level 4 or above			Achieved level 4 or above			Achieved level 4 or above	
Group	N of valid results	*n*	% (95% CI)[b] or [% range]	N of valid results	*n*	% (95% CI)[b] or [% range]	N of valid results	*n*	% (95% CI)[b] or [% range]
Controls	36,533	28,604	78.3 (77.9, 78.7)	59,090	47,597	80.6 (80.2, 80.9)	18,850	16,349	86.7 (86.2, 87.2)
All isolated structural anomalies	5614	4037	71.9 (70.7, 73.1)	9450	6895	73.0 (72.1, 73.9)	2785	2252	80.9 (79.4, 82.3)
Nervous system									
Encephalocele	[d]	[d]	[26–50]	[d]	[d]	[26–50]	[d]	[d]	[76–100]
Spina Bifida	40	25	62.5 (45.8, 77.3)	73	36	49.3 (37.4, 61.3)	27	[e]	[76–100]
Hydrocephalus	51	16	31.4 (19.1, 45.9)	93	34	36.6 (26.8, 47.2)	23	10	43.5 (23.2, 65.5)
Severe microcephaly	39	[d]	[0–25]	56	[d]	[0–25]	20	[d]	[0–25]
Arhinencephaly/holoprosencephaly	[d]	[d]	[0–25]	[d]	[d]	[0–25]	[d]	[d]	[0–25]
Eye									
Anophthalmos/microphthalmos	12	[e]	[76–100]	21	[e]	[51–75]	[d]	[d]	[51–75]
Anophthalmos	[d]	[d]	[51–75]	[d]	[e]	[26–50]	[d]	[d]	[51–75]
Congenital cataract	39	29	74.4 (57.9, 87.0)	59	37	62.7 (49.1, 75.0)	18	[e]	[51–75]
Congenital glaucoma	[d]	[d]	[51–75]	[d]	[d]	[51–75]	[d]	[d]	[76–100]
Ear, face and neck									
Anotia	[d]	[d]	[51–75]	[d]	[d]	[76–100]	[d]	[d]	[76–100]
Congenital heart defects (CHD)									
ALL CHD	2115	1557	73.6 (71.7, 75.5)	3395	2466	72.6 (71.1, 74.1)	1204	983	81.6 (79.3, 83.8)
Severe CHD[c]	645	446	69.1 (65.4, 72.7)	1011	708	70.0 (67.1, 72.8)	346	273	78.9 (74.2, 83.1)
Common arterial truncus	10	[e]	[51–75]	11	[e]	[26–50]	[d]	[d]	[76–100]
Double outlet right ventricle	24	[e]	[51–75]	42	28	66.7 (50.5, 80.4)	15	[e]	[76–100]
Transposition of great vessels	148	104	70.3 (62.2, 77.5)	234	175	74.8 (68.7, 80.2)	73	[e]	[76–100]
Single ventricle	12	[e]	[51–75]	17	[e]	[51–75]	[d]	[d]	[76–100]
Ventricular septal defect	1087	830	76.4 (73.7, 78.9)	1664	1246	74.9 (72.7, 76.9)	637	531	83.4 (80.2, 86.2)
Atrial septal defect	291	202	69.4 (63.8, 74.7)	532	374	70.3 (66.2, 74.2)	151	122	80.8 (73.6, 86.7)
Atrioventricular septal defect	51	38	74.5 (60.4, 85.7)	84	61	72.6 (61.8, 81.8)	27	[e]	[76–100]
Tetralogy of Fallot	103	64	62.1 (52.0, 71.5)	164	106	64.6 (56.8, 71.9)	60	41	68.3 (55.0, 79.7)
Triscuspid atresia and stenosis	14	[e]	[76–100]	25	[e]	[76–100]	[d]	[d]	[76–100]
Ebstein's anomaly	14	[e]	[26–50]	24	[e]	[51–75]	[d]	[d]	[51–75]

TABLE 1 (Continued)

Group	English language (2004/05–2011/12)[a]			Mathematics (2004/05–2014/15)[a]			Science (2004/05–2008/09)[a]		
		Achieved level 4 or above			Achieved level 4 or above			Achieved level 4 or above	
	N of valid results	*n*	% (95% CI)[b] or [% range]	N of valid results	*n*	% (95% CI)[b] or [% range]	N of valid results	*n*	% (95% CI)[b] or [% range]
Pulmonary valve stenosis	249	182	73.1 (67.1, 78.5)	380	274	72.1 (67.3, 76.6)	161	126	78.3 (71.1, 84.4)
Pulmonary valve atresia	10	[e]	[51–75]	26	15	57.7 (36.9, 76.6)	[d]	[d]	[76–100]
Aortic valve atresia/stenosis	81	61	75.3 (64.5, 84.2)	114	87	76.3 (67.4, 83.8)	49	39	79.6 (65.7, 89.8)
Mitral valve anomalies	34	22	64.7 (46.5, 80.3)	54	33	61.1 (46.9, 74.1)	18	[e]	[76–100]
Hypoplastic left heart	13	[e]	[26–50]	25	11	44.0 (24.4, 65.1)	[d]	[d]	[51–75]
Hypoplastic right heart	[d]	[d]	[76–100]	[d]	[d]	[76–100]	[d]	[d]	[76–100]
Coarctation of aorta	151	107	70.9 (62.9, 78.0)	241	170	70.5 (64.3, 76.2)	70	54	77.1 (65.6, 86.3)
Aortic atresia/interrupted aortic arch	[d]	[d]	[51–75]	10	[e]	[51–75]	[d]	[d]	[0–25]
Total anomalous pulmonary venous return	29	[e]	[51–75]	47	33	70.2 (55.1, 82.7)	16	[e]	[76–100]
PDA as only CHD in term infants (GA ≥37 weeks)	31	20	64.5 (45.4, 80.8)	108	72	66.7 (56.9, 75.4)	0	0	
Respiratory									
Choanal atresia	11	[e]	[51–75]	17	[e]	[76–100]	[d]	[d]	[76–100]
Cystic adenomatous malformation of lung	29	[e]	[51–75]	46	[e]	[76–100]	[d]	[d]	[76–100]
Orofacial clefts									
Cleft lip with or without cleft palate	383	266	69.5 (64.6, 74.0)	600	442	73.7 (69.9, 77.2)	197	160	81.2 (75.1, 86.4)
Cleft palate	249	178	71.5 (65.4, 77.0)	367	249	67.8 (62.8, 72.6)	117	88	75.2 (66.4, 82.7)
Digestive system									
Oesophageal atresia with or without tracheo-oesophageal fistula	65	51	78.5 (66.5, 87.7)	85	67	78.8 (68.6, 86.9)	29	[e]	[76–100]
Duodenal atresia or stenosis	36	[e]	[76–100]	59	47	79.7 (67.2, 89.0)	13	13	100.0 (75.3, 100.0)
Atresia or stenosis of other parts of small intestine	29	[e]	[76–100]	35	[e]	[76–100]	[d]	[d]	[76–100]
Ano-rectal atresia and stenosis	51	32	62.7 (48.1, 75.9)	86	62	72.1 (61.4, 81.2)	20	[e]	[51–75]
Hirschsprung's disease	42	31	73.8 (58.0, 86.1)	78	63	80.8 (70.3, 88.8)	15	[e]	[51–75]
Atresia of bile ducts	[d]	[d]	[76–100]	[d]	[e]	[76–100]	[d]	[d]	100.0 (2.5, 100.0)
Diaphragmatic hernia	62	43	69.4 (56.3, 80.4)	96	70	72.9 (62.9, 81.5)	36	[e]	[76–100]

(Continues)

TABLE 1 (Continued)

Group	English language (2004/05–2011/12)[a]			Mathematics (2004/05–2014/15)[a]			Science (2004/05–2008/09)[a]		
		Achieved level 4 or above			Achieved level 4 or above			Achieved level 4 or above	
	N of valid results	*n*	% (95% CI)[b] or [% range]	N of valid results	*n*	% (95% CI)[b] or [% range]	N of valid results	*n*	% (95% CI)[b] or [% range]
Abdominal wall defects									
Gastroschisis	127	90	70.9 (62.1, 78.6)	231	166	71.9 (65.6, 77.6)	73	61	83.6 (73.0, 91.2)
Omphalocele	27	[e]	[51–75]	52	[e]	[76–100]	12	[e]	[76–100]
Urinary									
Multicystic renal dysplasia	131	101	77.1 (68.9, 84.0)	218	170	78.0 (71.9, 83.3)	73	60	82.2 (71.5, 90.2)
Congenital hydronephrosis	409	321	78.5 (74.2, 82.4)	710	570	80.3 (77.2, 83.1)	202	182	90.1 (85.1, 93.8)
Genital									
Hypospadias	248	185	74.6 (68.7, 79.9)	592	488	82.4 (79.1, 85.4)	59	[e]	[76–100]
Indeterminate sex	15	[e]	[51–75]	22	[e]	[51–75]	12	[e]	[76–100]
Limb									
Limb reduction defects	110	83	75.5 (66.3, 83.2)	179	138	77.1 (70.2, 83.0)	60	[e]	[76–100]
Club foot–talipes equinovarus	124	95	76.6 (68.2, 83.7)	217	159	73.3 (66.9, 79.0)	51	[e]	[76–100]
Hip dislocation and/or dysplasia	32	[e]	[76–100]	52	[e]	[76–100]	[d]	[d]	[76–100]
Polydactyly	127	98	77.2 (68.9, 84.1)	313	252	80.5 (75.7, 84.8)	28	[e]	[76–100]
Syndactyly	105	79	75.2 (65.9, 83.1)	224	176	78.6 (72.6, 83.8)	19	[e]	[76–100]
Other anomalies									
Craniosynostosis	25	[d]	[26–50]	41	27	65.9 (49.4, 79.9)	16	[e]	[51–75]
Situs inversus	[d]	[d]	[26–50]	11	[e]	[51–75]	[d]	[d]	[76–100]
Chromosomal									
Down syndrome	450	[d]	[0–25]	751	12	1.6 (0.8, 2.8)	203	[d]	[0–25]
Turner syndrome	72	53	73.6 (61.9, 83.3)	101	58	57.4 (47.2, 67.2)	40	29	72.5 (56.1, 85.4)
Klinefelter syndrome	36	12	33.3 (18.6, 51.0)	62	29	46.8 (34.0, 59.9)	25	12	48.0 (27.8, 68.7)

Abbreviations: CHD, congenital heart defect; CI, confidence interval; GA, gestational age; PDA, patent ductus arteriosus.

[a]The years in which children were tested differed according to subject and hence the denominators differed for each subject.

[b]Exact binomial confidence intervals. Where counts have been suppressed the quartile that includes the estimated percentage is indicated by [ ].

[c]Subgroups included in Severe CHD are indicated in Table S2.

[d]Suppressed small count (<10) with [ ] indicating the quartile that includes the estimated percentage.

[e]Secondary suppression (<10 did not achieve level 4 or above).

the expected level (level 4 and above) at KS2 for EUROCAT children and control children. At age 11, 71.9% (95% CI 70.7%, 73.1%) of EUROCAT children achieved the expected level of achievement in the English language compared with 78.3% (95% CI 77.9%, 78.7%) of control children. For both EUROCAT and controls, proportionally more children achieved expected levels in Science, followed by Mathematics and then English. Compared with control children, EUROCAT children were less likely to achieve expected attainment levels in English, Mathematics and Science (RR 0.92 [95% CI 0.90, 0.93], RR 0.91 [95% CI 0.89, 0.92] and RR 0.93 [95% CI 0.91, 0.95], respectively); adjusting for FSME did not materially alter the results (Table 2). There were variations between isolated CA subgroups: children with congenital hydrocephalus, spina bifida, severe microcephaly, hypoplastic left heart and craniosynostosis were least likely to achieve expected levels in all or some subjects, while no differences were evident for children with anomalies of the digestive system (excepting children with ano-rectal atresia/stenosis in the English language), multicystic renal dysplasia, limb reduction defects and boys with hypospadias. Only 1.6% of children with Down syndrome (DS) achieved the expected level in Mathematics (adjusted RR 0.02, 95% CI 0.01, 0.03), ≤2.0% in English and ≤4.5% in Science (percentages calculated assuming the maximum suppressed value). Girls with Turner syndrome were similarly likely to achieve expected levels in English and Science as control girls, but did worse in Mathematics (adjusted RR 0.70, 95% CI 0.59, 0.83); boys with Klinefelter syndrome performed less well across all subjects compared with control boys.

Table 3 shows the number (%) of children and the RRs (95% CIs) of achieving level 2 at KS4 (5+ GCSEs and equivalents at grades A*-C, including GCSE English and Mathematics), for EUROCAT children compared with control children. After adjusting for FSME, the RR of achieving level 2 was 0.88 (95% CI 0.86, 0.91) for children with isolated structural CAs overall compared to control children. Among children with isolated CAs, there was substantial variation in achievement between specific CAs, ranging from expected low achievement for children with hydrocephalus and severe microcephaly to comparable achievement for other subgroups, although many are small samples with wide CIs. Children with atrial septal defect, tetralogy of fallot, cleft lip with/without cleft palate and ano-rectal atresia/stenosis were more likely to underperform at age 16 compared to control children, as were children with chromosomal anomalies (Down, Turner and Klinefelter syndromes). The sensitivity analysis of the effect of missing FSME data on the KS4 results showed that they would not have materially changed the adjusted ORs.

4 | COMMENT

4.1 | Principal findings

This study found that over 70% of children born with isolated CAs in England achieved the expected academic level at age 11 and about 47% at age 16 compared with approximately 78%–87% and 53% for control children, respectively. There was substantial variation in attainment between specific isolated CAs, with no differences evident for children with anomalies of the digestive system, multicystic renal dysplasia, limb reduction defects and boys with hypospadias. However, as expected, academic achievement was significantly lower for children with brain CAs (e.g. hydrocephalus and severe microcephaly) and for a heterogeneous group of children with severe CHDs. Where there was an attainment gap between children with specific isolated CAs and control children, it remained after adjustment for FSME, a proxy of socioeconomic deprivation, a well-established factor associated with lower academic achievement.

4.2 | Strengths of the study

This multi-registry linked cohort study is population-based and includes all children with CAs in four English EUROCAT registries' catchment areas and a random sample of frequency-matched children from the background population recorded in the NPD. The EUROCAT registries are characterised by high levels of case ascertainment and a standardised approach to the classification and coding of CAs. Given the well-recognised association between academic underachievement and socioeconomic deprivation, we selected the comparison group based on geographical area in addition to age and sex and adjusted for individual-level deprivation (FSME) in our analyses. The use of age-matched control children for comparison allows for adjustment of time trends and for systemic changes in the education system introduced over the study period. To our knowledge, this is the first European study of school achievement of children with a wide range of isolated structural CAs in different organ systems at ages 11 and 16 compared to control children originating from the same school population.

4.3 | Limitations of the data

Since the four regional CA registries do not cover all of England, our results may not be fully representative of the outcomes in other regions. Nonetheless, as comparisons have been made with geographically matched children from the background population, we can be reasonably confident in the general validity of the estimated differences between children with and without CAs. Due to names not being routinely collected in the earlier years by the CA registries and addresses not being updated, about one-fifth of EUROCAT children could not be linked to the NPD, which have resulted in a smaller cohort available for analysis and some potential for bias. This is mitigated by the fact that non-linkage due to poor identifiers is unlikely to be associated with educational outcomes.

Around 5% of children attend private schools in England and would be missing from our data, but as attendance at a private school is highly dependent on their parents' choices and finances rather than the child's CA, we do not believe this to be a source of bias. Related work by our group showed that only 5% of children with

TABLE 2 Key stage 2 (KS2) level of attainment: unadjusted and adjusted risk ratios (95% CI) of achieving level 4 and above (expected level) for EUROCAT children versus control children by school subject, estimated by generalised linear models.

	Achieved level 4 or above (expected level)					
	English language[a]		Mathematics[a]		Science[a]	
	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)
Controls	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
All isolated structural anomalies	0.92 (0.90, 0.93)	0.92 (0.90, 0.93)	0.91 (0.89, 0.92)	0.91 (0.89, 0.92)	0.93 (0.91, 0.95)	0.93 (0.91, 0.95)
Nervous system						
Encephalocele	[f]	0.34 (0.07, 1.75)	[f]	0.48 (0.20, 1.13)	[f]	0.91 (0.54, 1.53)
Spina Bifida	0.80 (0.63, 1.01)	0.81 (0.64, 1.03)	0.61 (0.49, 0.77)	0.62 (0.49, 0.79)	[f]	0.90 (0.73, 1.10)
Hydrocephalus	0.40 (0.27, 0.60)	0.41 (0.27, 0.61)	0.45 (0.35, 0.59)	0.46 (0.35, 0.60)	0.50 (0.31, 0.80)	0.51 (0.32, 0.81)
Severe microcephaly	[f]	0.07 (0.02, 0.25)	[f]	0.13 (0.06, 0.29)	[f]	0.06 (0.01, 0.39)
Arhinencephaly/holoprosencephaly	[g]	[g]	[g]	[g]	[g]	[g]
Eye						
Anophthalmos/microphthalmos	[f]	0.95 (0.69, 1.30)	[f]	0.77 (0.55, 1.08)	[f]	0.74 (0.42, 1.31)
Anophthalmos	[f]	0.88 (0.37, 2.11)	[f]	0.54 (0.19, 1.55)	[f]	0.56 (0.14, 2.23)
Congenital cataract	0.95 (0.79, 1.14)	0.91 (0.76, 1.10)	0.78 (0.64, 0.95)	0.77 (0.63, 0.93)	[f]	0.81 (0.61, 1.09)
Congenital glaucoma	[f]	0.81 (0.36, 1.80)	[f]	0.64 (0.28, 1.42)	[f]	1.12 (1.11, 1.12)
Ear, face and neck						
Anotia	[f]	0.81 (0.36, 1.80)	[f]	1.02 (0.76, 1.38)	[f]	1.12 (1.11, 1.12)
Congenital heart defects (CHD)						
ALL CHD	0.94 (0.92, 0.97)	0.94 (0.92, 0.97)	0.90 (0.88, 0.92)	0.90 (0.88, 0.92)	0.94 (0.92, 0.97)	0.94 (0.91, 0.97)
Severe CHD[c]	0.88 (0.84, 0.93)	0.89 (0.85, 0.93)	0.87 (0.83, 0.91)	0.87 (0.84, 0.91)	0.91 (0.86, 0.96)	0.91 (0.86, 0.96)
Common arterial truncus	[f]	0.77 (0.48, 1.23)	[f]	0.57 (0.31, 1.06)	[f]	0.87 (0.59, 1.28)
Double outlet right ventricle	[f]	0.88 (0.66, 1.17)	0.83 (0.67, 1.03)	0.83 (0.67, 1.03)	[f]	1.03 (0.84, 1.26)
Transposition of great vessels	0.90 (0.81, 1.00)	0.90 (0.82, 1.00)	0.93 (0.86, 1.00)	0.93 (0.86, 1.00)	[f]	1.01 (0.92, 1.10)
Single ventricle	[f]	0.88 (0.60, 1.30)	[f]	0.81 (0.57, 1.14)	[f]	0.90 (0.63, 1.29)
Ventricular septal defect	0.98 (0.94, 1.01)	0.98 (0.95, 1.01)	0.93 (0.90, 0.96)	0.93 (0.90, 0.95)	0.96 (0.93, 1.00)	0.96 (0.93, 0.99)
Atrial septal defect	0.89 (0.82, 0.96)	0.88 (0.82, 0.95)	0.87 (0.83, 0.92)	0.87 (0.83, 0.92)	0.93 (0.86, 1.01)	0.92 (0.85, 1.00)
Atrioventricular septal defect	0.95 (0.81, 1.12)	0.96 (0.82, 1.12)	0.90 (0.79, 1.03)	0.90 (0.80, 1.03)	[f]	1.06 (0.95, 1.19)
Tetralogy of Fallot	0.79 (0.68, 0.92)	0.81 (0.70, 0.93)	0.80 (0.72, 0.90)	0.81 (0.73, 0.91)	0.79 (0.66, 0.94)	0.79 (0.67, 0.94)
Triscuspid atresia and stenosis	[f]	1.08 (0.88, 1.32)	[f]	0.98 (0.81, 1.18)	[f]	1.02 (0.80, 1.28)
Ebstein's anomaly	[f]	0.55 (0.30, 1.00)	[f]	0.79 (0.58, 1.07)	[f]	0.59 (0.29, 1.20)

TABLE 2 (Continued)

	Achieved level 4 or above (expected level)					
	English language[a]		Mathematics[a]		Science[a]	
	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)
Pulmonary valve stenosis	0.93 (0.87, 1.01)	0.95 (0.88, 1.02)	0.90 (0.84, 0.95)	0.90 (0.84, 0.96)	0.90 (0.83, 0.98)	0.91 (0.83, 0.98)
Pulmonary valve atresia	[f]	0.87 (0.59, 1.28)	0.72 (0.52, 1.00)	0.70 (0.51, 0.97)	[f]	1.12 (1.11, 1.12)
Aortic valve atresia/stenosis	0.96 (0.85, 1.09)	0.95 (0.84, 1.08)	0.95 (0.86, 1.05)	0.94 (0.85, 1.04)	0.92 (0.80, 1.06)	0.91 (0.79, 1.05)
Mitral valve anomalies	0.83 (0.64, 1.06)	0.90 (0.71, 1.14)	0.76 (0.61, 0.94)	0.77 (0.62, 0.96)	[f]	0.98 (0.77, 1.24)
Hypoplastic left heart	[f]	0.50 (0.26, 0.97)	0.55 (0.35, 0.85)	0.56 (0.36, 0.86)	[f]	0.71 (0.37, 1.36)
Hypoplastic right heart	[f]	0.97 (0.63, 1.51)	[f]	0.93 (0.65, 1.32)	[f]	1.12 (1.11, 1.12)
Coarctation of aorta	0.91 (0.82, 1.00)	0.90 (0.81, 0.99)	0.88 (0.81, 0.95)	0.87 (0.80, 0.94)	0.89 (0.78, 1.01)	0.89 (0.78, 1.01)
Aortic atresia/interrupted aortic arch	[f]	0.61 (0.15, 2.43)	[f]	0.74 (0.45, 1.23)	[g]	[g]
Total anomalous pulmonary venous return	[f]	0.90 (0.73, 1.12)	0.87 (0.72, 1.05)	0.87 (0.72, 1.05)	[f]	0.85 (0.64, 1.11)
PDA as only CHD in term infants (GA ≥37 weeks)	0.82 (0.63, 1.07)	0.82 (0.63, 1.07)	0.83 (0.72, 0.95)	0.83 (0.73, 0.96)	[g]	[g]
Respiratory						
Choanal atresia	[f]	0.77 (0.49, 1.21)	[f]	0.91 (0.70, 1.19)	[f]	0.89 (0.58, 1.39)
Cystic adenomatous malformation of lung	[f]	0.92 (0.73, 1.16)	[f]	1.01 (0.89, 1.15)	[f]	0.96 (0.66, 1.38)
Orofacial clefts						
Cleft lip with or without cleft palate	0.89 (0.83, 0.95)	0.88 (0.83, 0.94)	0.91 (0.87, 0.96)	0.91 (0.87, 0.96)	0.94 (0.88, 1.00)	0.92 (0.86, 0.99)
Cleft palate	0.91 (0.84, 0.99)	0.91 (0.84, 0.98)	0.84 (0.78, 0.90)	0.84 (0.78, 0.90)	0.87 (0.78, 0.96)	0.86 (0.78, 0.95)
Digestive system						
Oesophageal atresia with or without tracheo-oesophageal fistula	1.00 (0.88, 1.14)	0.99 (0.87, 1.12)	0.98 (0.88, 1.09)	0.98 (0.88, 1.09)	[f]	0.97 (0.84, 1.12)
Duodenal atresia or stenosis	[f]	1.09 (0.97, 1.23)	0.99 (0.87, 1.13)	1.00 (0.88, 1.13)	1.15 (1.15, 1.16)	1.13 (1.10, 1.16)
Atresia or stenosis of other parts of small intestine	[f]	0.95 (0.77, 1.18)	[f]	0.95 (0.79, 1.13)	[f]	1.03 (0.81, 1.31)
Ano-rectal atresia and stenosis	0.80 (0.65, 0.99)	0.82 (0.67, 0.99)	0.90 (0.78, 1.02)	0.90 (0.80, 1.02)	[f]	0.83 (0.63, 1.09)
Hirschsprung's disease	0.94 (0.79, 1.13)	0.95 (0.80, 1.14)	1.00 (0.90, 1.12)	1.00 (0.90, 1.12)	[f]	0.86 (0.64, 1.16)
Atresia of bile ducts	[f]	1.02 (0.64, 1.63)	[f]	1.13 (0.88, 1.46)	[f]	1.12 (1.11, 1.12)
Diaphragmatic hernia	0.89 (0.75, 1.05)	0.90 (0.77, 1.06)	0.91 (0.80, 1.02)	0.91 (0.81, 1.03)	[f]	0.90 (0.75, 1.07)

(Continues)

TABLE 2 (Continued)

	Achieved level 4 or above (expected level)					
	English language[a]		Mathematics[a]		Science[a]	
	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)
Abdominal wall defects						
Gastroschisis	0.91 (0.81, 1.01)	0.94 (0.84, 1.05)	0.89 (0.82, 0.97)	0.92 (0.85, 0.99)	0.96 (0.87, 1.07)	0.99 (0.90, 1.09)
Omphalocele	[f]	0.84 (0.65, 1.09)	[f]	1.02 (0.90, 1.15)	[f]	0.97 (0.77, 1.21)
Urinary						
Multicystic renal dysplasia	0.98 (0.90, 1.08)	0.99 (0.90, 1.08)	0.97 (0.90, 1.04)	0.97 (0.90, 1.04)	0.95 (0.85, 1.05)	0.94 (0.84, 1.05)
Congenital hydronephrosis	1.00 (0.95, 1.05)	0.99 (0.94, 1.04)	1.00 (0.96, 1.03)	0.99 (0.95, 1.03)	1.04 (0.99, 1.09)	1.02 (0.98, 1.07)
Genital						
Hypospadias[d]	1.01 (0.94, 1.09)	1.01 (0.94, 1.08)	1.02 (0.99, 1.06)	1.02 (0.99, 1.06)	[f]	0.97 (0.88, 1.08)
Indeterminate sex	[f]	0.79 (0.54, 1.16)	[f]	0.74 (0.53, 1.02)	[f]	0.89 (0.66, 1.20)
Limb						
Limb reduction defects	0.96 (0.87, 1.07)	0.95 (0.86, 1.06)	0.96 (0.88, 1.04)	0.95 (0.88, 1.03)	[f]	0.99 (0.89, 1.10)
Club foot–talipes equinovarus	0.98 (0.89, 1.08)	0.95 (0.86, 1.06)	0.91 (0.84, 0.99)	0.90 (0.83, 0.98)	[f]	1.05 (0.97, 1.14)
Hip dislocation and/or dysplasia	[f]	1.09 (0.96, 1.24)	[f]	1.02 (0.91, 1.15)	[f]	1.14 (1.10, 1.17)
Polydactyly	0.99 (0.90, 1.08)	0.98 (0.89, 1.08)	1.00 (0.95, 1.06)	0.99 (0.94, 1.05)	[f]	0.97 (0.83, 1.14)
Syndactyly	0.96 (0.86, 1.07)	0.95 (0.85, 1.06)	0.98 (0.91, 1.04)	0.97 (0.91, 1.04)	[f]	0.97 (0.80, 1.18)
Other anomalies						
Craniosynostosis	[f]	0.46 (0.28, 0.78)	0.82 (0.66, 1.02)	0.82 (0.66, 1.01)	[f]	0.71 (0.49, 1.04)
Situs inversus	[f]	0.44 (0.08, 2.50)	[f]	0.90 (0.62, 1.31)	[f]	1.21 (1.08, 1.35)
Chromosomal						
Down syndrome	[f]	0.02 (0.01, 0.05)	0.02 (0.01, 0.03)	0.02 (0.01, 0.03)	[f]	0.03 (0.01, 0.07)
Turner syndrome[e]	0.94 (0.82, 1.08)	0.95 (0.83, 1.09)	0.71 (0.60, 0.84)	0.70 (0.59, 0.83)	0.84 (0.69, 1.01)	0.84 (0.70, 1.02)
Klinefelter syndrome[d]	0.45 (0.28, 0.72)	0.44 (0.28, 0.69)	0.58 (0.45, 0.76)	0.57 (0.44, 0.74)	0.56 (0.37, 0.84)	0.55 (0.36, 0.82)

Abbreviations: CHD, congenital heart defect; CI, confidence interval; EUROCAT, European network of population-based registries for the surveillance of congenital anomalies; GA, gestational age; PDA, patent ductus arteriosus; RR, risk ratio.

[a]The number of pupils with valid results for each school subject is reported in Table 1.

[b]Adjusted for Free School Meals eligibility (proxy of socioeconomic deprivation).

[c]Subgroups included in Severe CHD are indicated in Table S2.

[d]Compared with control boys only.

[e]Compared with control girls only.

[f]Unadjusted RRs suppressed to prevent derivation of small counts. Adjusted RRs do not disclose small counts as the number of children in adjusted models have not been provided.

[g]Insufficient data for estimation.

TABLE 3 Key stage 4 (KS4) level of attainment: number, percentage of children and unadjusted and adjusted risk ratios (RR) of achieving 5 or more General Certificate of Secondary Education (GCSE) and equivalents at grades A*-C (Level 2), including GCSE English and Mathematics, for EUROCAT children versus the comparison group (controls).

		Achieved 5 or more GCSE and equivalents at grades A*-C (Level 2) including GCSE English and Mathematics (2009/10–2015/16)			
	N pupils with a valid result	*n*	% (95% CI)[a] or [% range]	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)
Controls	32,770	17,196	52.5 (51.9, 53.0)	1.00 (Reference)	1.00 (Reference)
All isolated structural anomalies	4824	2262	46.9 (45.5, 48.3)	0.89 (0.87, 0.92)	0.88 (0.86, 0.91)
Nervous system					
Encephalocele	[f]	[f]	[0–25]	[g]	0.38 (0.07, 2.14)
Spina Bifida	39	15	38.5 (23.4, 55.4)	0.74 (0.50, 1.11)	0.81 (0.56, 1.17)
Hydrocephalus	42	[f]	[0–25]	[g]	0.33 (0.17, 0.65)
Severe microcephaly	36	[f]	[0–25]	[g]	0.11 (0.03, 0.42)
Arhinencephaly/holoprosencephaly	[f]	0	[0–25]	[i]	[i]
Eye					
Anophthalmos/microphthalmos	[f]	[f]	[26–50]	[g]	0.80 (0.35, 1.81)
Anophthalmos	[f]	0	[0–25]	[i]	[i]
Congenital cataract	32	19	59.4 (40.6, 76.3)	1.15 (0.86, 1.53)	1.22 (0.93, 1.60)
Congenital glaucoma	[f]	[f]	100.0 (29.2, 100.0)	[g]	1.73 (1.72, 1.75)
Ear, face and neck					
Anotia	[f]	[f]	100.0 (15.8, 100.0)	[g]	1.73 (1.72, 1.75)
Congenital heart defects (CHD)					
ALL CHD	1865	879	47.1 (44.8, 49.4)	0.91 (0.86, 0.95)	0.90 (0.85, 0.94)
Severe CHD[c]	563	247	43.9 (39.7, 48.1)	0.85 (0.77, 0.93)	0.84 (0.76, 0.92)
Common arterial truncus	10	[h]	[51–75]	[g]	0.91 (0.50, 1.65)
Double outlet right ventricle	22	[f]	[26–50]	[g]	0.91 (0.58, 1.44)
Transposition of great vessels	128	57	44.5 (35.7, 53.6)	0.86 (0.71, 1.04)	0.86 (0.71, 1.05)
Single ventricle	10	[h]	[26–50]	[g]	0.77 (0.38, 1.57)
Ventricular septal defect	977	487	49.8 (46.7, 53.0)	0.96 (0.90, 1.03)	0.95 (0.89, 1.01)
Atrial septal defect	247	102	41.3 (35.1, 47.7)	0.80 (0.69, 0.92)	0.82 (0.71, 0.94)
Atrioventricular septal defect	46	17	37.0 (23.2, 52.5)	0.71 (0.49, 1.04)	0.72 (0.50, 1.04)
Tetralogy of Fallot	96	33	34.4 (25.0, 44.8)	0.66 (0.50, 0.87)	0.64 (0.49, 0.85)
Triscuspid atresia and stenosis	14	[h]	[51–75]	[g]	1.06 (0.65, 1.75)
Ebstein's anomaly	12	[h]	[26–50]	[g]	0.72 (0.31, 1.67)
Pulmonary valve stenosis	232	103	44.4 (37.9, 51.0)	0.86 (0.74, 0.99)	0.88 (0.77, 1.01)
Pulmonary valve atresia	[f]	[f]	[26–50]	[g]	0.77 (0.37, 1.60)
Aortic valve atresia/stenosis	75	40	53.3 (41.4, 64.9)	1.03 (0.83, 1.27)	0.98 (0.79, 1.22)
Mitral valve anomalies	26	[f]	[26–50]	[g]	0.71 (0.42, 1.20)
Hypoplastic left heart	10	[h]	[26–50]	[g]	0.61 (0.25, 1.48)
Hypoplastic right heart	[f]	[f]	[76–100]	[g]	1.48 (0.75, 2.92)
Coarctation of aorta	126	61	48.4 (39.4, 57.5)	0.94 (0.78, 1.12)	0.94 (0.79, 1.12)
Aortic atresia/interrupted aortic arch	[f]	0	[0–25]	[i]	[i]
Total anomalous pulmonary venous return	22	[f]	[26–50]	[g]	0.76 (0.47, 1.23)
PDA as only CHD in term infants (GA ≥37 weeks)	10	[h]	[26–50]	[g]	0.55 (0.22, 1.39)
Respiratory					
Choanal atresia	[f]	[f]	[76–100]	[g]	1.35 (0.95, 1.91)
Cystic adenomatous malformation of lung	22	[f]	[26–50]	[g]	0.91 (0.60, 1.40)

(Continues)

TABLE 3 (Continued)

	N pupils with a valid result	Achieved 5 or more GCSE and equivalents at grades A*-C (Level 2) including GCSE English and Mathematics (2009/10–2015/16)			
		n	% (95% CI)[a] or [% range]	Unadjusted RR (95% CI)	RR adjusted[b] (95% CI)
Orofacial clefts					
Cleft lip with or without cleft palate	336	140	41.7 (36.3, 47.1)	0.80 (0.71, 0.91)	0.79 (0.70, 0.89)
Cleft palate	206	96	46.6 (39.6, 53.7)	0.90 (0.78, 1.04)	0.91 (0.78, 1.05)
Digestive system					
Oesophageal atresia with or without tracheo-oesophageal fistula	57	31	54.4 (40.7, 67.6)	1.05 (0.83, 1.33)	1.00 (0.79, 1.27)
Duodenal atresia or stenosis	30	18	60.0 (40.6, 77.3)	1.16 (0.87, 1.55)	1.05 (0.77, 1.43)
Atresia or stenosis of other parts of small intestine	15	[h]	[51–75]	[g]	1.20 (0.82, 1.74)
Ano-rectal atresia and stenosis	42	13	31.0 (17.6, 47.1)	0.60 (0.38, 0.94)	0.64 (0.42, 0.99)
Hirschsprung's disease	36	16	44.4 (27.9, 61.9)	0.86 (0.60, 1.24)	0.88 (0.61, 1.25)
Atresia of bile ducts	[f]	[f]	[51–75]	[g]	1.16 (0.52, 2.57)
Diaphragmatic hernia	49	21	42.9 (28.8, 57.8)	0.83 (0.60, 1.14)	0.85 (0.62, 1.17)
Abdominal wall defects					
Gastroschisis	106	43	40.6 (31.1, 50.5)	0.78 (0.62, 0.99)	0.83 (0.66, 1.04)
Omphalocele	23	[h]	[51–75]	[g]	1.15 (0.83, 1.60)
Urinary					
Multicystic renal dysplasia	120	64	53.3 (44.0, 62.5)	1.03 (0.87, 1.22)	0.98 (0.84, 1.16)
Congenital hydronephrosis	358	181	50.6 (45.3, 55.9)	0.98 (0.88, 1.08)	0.94 (0.85, 1.04)
Genital					
Hypospadias[d]	195	95	48.7 (41.5, 56.0)	0.94 (0.81, 1.09)	0.93 (0.81, 1.07)
Indeterminate sex	18	[f]	[26–50]	[g]	0.74 (0.40, 1.36)
Limb					
Limb reduction defects	99	47	47.5 (37.3, 57.8)	0.92 (0.75, 1.13)	0.93 (0.75, 1.14)
Club foot–talipes equinovarus	111	60	54.1 (44.3, 63.6)	1.04 (0.88, 1.24)	0.98 (0.81, 1.17)
Hip dislocation and/or dysplasia	25	[h]	[51–75]	[g]	1.39 (1.11, 1.74)
Polydactyly	108	54	50.0 (40.2, 59.8)	0.97 (0.80, 1.17)	0.96 (0.79, 1.16)
Syndactyly	82	42	51.2 (39.9, 62.4)	0.99 (0.80, 1.22)	0.95 (0.77, 1.17)
Other anomalies					
Craniosynostosis	24	[f]	[26–50]	[g]	0.71 (0.43, 1.16)
Situs inversus	[f]	[f]	[51–75]	[g]	1.16 (0.52, 2.57)
Chromosomal					
Down syndrome	389	[f]	[0–25]	[g]	0.01 (0.00, 0.05)
Turner syndrome[e]	67	26	38.8 (27.1, 51.5)	0.74 (0.55, 1.00)	0.66 (0.48, 0.92)
Klinefelter syndrome[d]	39	[f]	[0–25]	[g]	0.20 (0.08, 0.51)

Abbreviations: CHD, congenital heart defect; CI, confidence interval; EUROCAT, European network of population-based registries for the surveillance of congenital anomalies; GA, gestational age; PDA, patent ductus arteriosus; RR, risk ratio.

[a]Exact binomial confidence intervals. Where counts have been suppressed the quartile that includes the estimated percentage is indicated by [ ].

[b]Adjusted for Free School Meals Eligibility (FSME). Overall proportion of children missing FSME: 5.0% (controls); 4.6% (all anomalies).

[c]Subgroups included in Severe CHD are indicated in Table S2.

[d]Compared with control boys only.

[e]Compared with control girls only.

[f]Denotes suppressed small count (<10).

[g]Unadjusted RRs suppressed to prevent derivation of small counts. Adjusted RRs do not disclose small counts as the number of children in adjusted models have not been provided.

[h]Secondary suppression (<10 did not achieve).

[i]Estimation not possible.

severe CHD in Finland did not plan to attend mainstream education beyond age 16[19]; this suggests that a relatively small proportion of children with isolated structural CAs do not attend mainstream schools (the corresponding figure for children with DS was 87% not planning to attend mainstream education in Finland).

Residual confounding by gestational age (not available for control children), co-morbidities, exposure to general anaesthetic during corrective surgery in early childhood and severity of CA are additional limitations. Moreover, medical protocols for the management of children with CAs have evolved and may have also differed by hospital, and our findings only report average outcomes. Lastly, we relied on the secondary use of the education database which has been affected by policy changes and is collected primarily for administrative rather than research purposes, and hence the quality of core attainment variables may not have been consistent over the years. For example, the changes and discontinuities in assessment standards over time have restricted the number of years with data available for analysis.

4.4 | Interpretation

The findings of our study are consistent with previous research on children with specific isolated/non-syndromic CAs.[20] Published studies in Europe, the USA and Australia using school assessment of academic achievements of children with CAs such as OFCs[10–12,21,22] and severe CHDs[6,8,23] showed a higher risk of academic underperformance at different ages compared to their peers without CAs. According to a longitudinal cohort study, lower performance in children with OFCs persists from elementary to high school (7–17 years).[13] Evidence on children with other CAs, such as gastrointestinal and abdominal wall anomalies, is more limited. Small studies using linked data from Arkansas, USA showed that complex gastroschisis and congenital diaphragmatic hernia were associated with poorer literacy during primary school[24,25]; parent surveys in the USA and Netherlands also indicated that children with these conditions could be at greater risk of learning difficulties.[26,27] A meta-analysis of children with oesophageal atresia reported neurodevelopmental impairment during school age (6–18 years).[28] Our study corroborates these findings and provides additional information on school achievement of children with a wider range of isolated CAs.

A previous English study found an independent association between school absence and lower attainment in children with OFCs aged 7 years.[10] A EUROlinkCAT study showed that children with CAs aged <1 year and 1–4 years in 11 European regions were hospitalised more often and stayed longer than control children.[29] If such trends persist in later childhood, then we expect school absence due to ill-health to adversely impact academic achievement. We could not explore the association of childhood morbidity with academic achievement as we did not manage to obtain permissions to link the data but hope to address this in future work.

Following parental request for positive information about their children's potential and achievement highlighted in focus groups across Europe with parents of children with a CA, our study's encouraging finding is that many children with major isolated structural CAs (excepting brain anomalies) achieve expected levels of attainment at both 11 and 16 years. Nonetheless, in both age groups, children with isolated CAs were on average more likely than their peers to underperform academically, indicating the need for special education support in these children and specific counselling for parents.

Traditionally, children with DS, which is associated with intellectual disability of varying degrees, were placed in special schools. Since the 1981 and 1993 Education Acts in the UK, proportions of children with DS aged 5–16 in mainstream schools increased from 4% to 38% between 1983 and 1996, with wide variations between different Local Education Authorities. The proportion of children with DS attending mainstream schools was 58% ($n=88$) in a recent UK survey of parental views on special education needs provision[30] and 65% in a survey of 569 parents on the educational experiences in pupils with DS in the UK. We found that around 2% of children with DS achieved the expected attainment levels at ages 11 and 16, respectively. These indicate that it is important for parents to be counselled on the likely achievements for their child. Growing evidence suggests that regular/mainstream schooling positively affects development of academic and communication skills in pupils with DS, compared to special schools, even when controlling for selective placement.[31–34] In addition to the need for high-level help and support in mainstream schools, secondary school pupils with DS need an individualised approach in developing academic, social and life skills, and good communication within school and with parents is a key to success.[35]

5 | CONCLUSIONS

Many children with isolated CAs achieved the expected academic level at ages 11 and 16, but there was a higher risk of underachievement for children with specific CAs compared to their peers. Results on educational outcomes for children born with specific CAs can be used for counselling parents regarding their child's potential to achieve expected academic levels at school and also for informing them on anticipated difficulties. Timely interventions to access special education services and identification of type of support needed are recommended to help children in reaching their full potential and improve their life chances.

AUTHOR CONTRIBUTIONS

Glinianaia and Tan share co-first authorship, that is, they contributed equally to the publication. Tan and Morris had full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. *Concept and design*: Glinianaia, Morris, Rankin, Tan. *Development of study methods, including standardisation of congenital anomalies, development of statistical analysis plan, writing analysis programs and statistical analysis*: Brigden, Evans, Glinianaia, Loane, Morris, Rankin,

Tan. *Data acquisition and interpretation of the results*: All authors. *Drafting of the manuscript*: Glinianaia, Tan. *Critical revision of the manuscript for important intellectual content*: All authors. *Obtained funding*: Morris, Rankin. *Supervision*: Morris, Rankin. All authors approved the final manuscript as submitted and agreed to be accountable for major aspects of the work.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The Department for Education is the controller of the data that support the findings of this study. Restrictions apply to the availability of these data, which were used under license for this study. Third-party requests for the data will require permission from the Department for Education.

ROLE OF THE FUNDER/SPONSOR

The funder had no involvement in study design, data analysis or interpretation. The views presented here are those of the authors only, and the European Commission is not responsible for any use that may be made of the information presented here.

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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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