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Adverse childhood experiences during childhood and academic attainment at age 7 and 11 years: an electronic birth cohort study

Annette Evans; Katie Hardcastle; Amrita Bandyopadhyay; Daniel Farewell; Ann John; Sara Long; Ronan A Lyons; Mark A Bellis; Shantini Paranjothy, PhD

Abstract

Objectives
Adverse childhood experiences (ACEs) have a negative impact on childhood health, but their impact on education outcomes is less well-known. We investigated whether or not ACEs were associated with reduced educational attainment at age 7 and 11 years.

Study design
The study design is a population based electronic cohort study

Methods
We analysed data from a total population electronic child cohort in Wales, UK. ACEs (exposures)were living with an adult household member with any of (i) serious mental illness, (ii) common mental disorder (CMD), (iii) an alcohol problem; (iv) child victimisation, (v) death of a household member and (vi) low family income. We used multilevel logistic regression to model exposure to these ACEs and not attaining the expected level at statutory education assessments, Key Stage (KS) 1 and KS2 separately, adjusted for known confounders including perinatal, socio-economic and school factors.

Results
There were 107,479 and 43,648 children included in the analysis, with follow-up to 6-7 years (KS1) and 10-11 years (KS2) respectively. An increased risk of not attaining the expected level at KS1 was associated with living with adult household members with CMD (adjusted odds ratio [aOR] 1.13 (95% confidence interval [CI] 1.09-1.17) or an alcohol problem (aOR 1.16 (95% CI 1.10-1.22), childhood victimisation (aOR 1.58 (95% CI 1.37-1.82), death of a household member (aOR 1.14 95% CI 1.04-1.25) and low family income (aOR 1.92 95% CI 1.84-2.01). Similar results were observed for KS2. Children with multiple adversities had substantially increased odds of not attaining the expected level at each educational assessment.

Conclusion
The educational potential of many children may not be achieved due to exposure to adversity in childhood. Affected children who come in to contact with services should have relevant information shared between health and care services, and schools to initiate and facilitate a coordinated approach towards providing additional support and help for them to fulfil their educational potential, and subsequent economic and social participation.

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Highlights

- first UK study to use routinely available healthcare data record-linked to education outcome data in a total population electronic child cohort to examine the cumulative impact of multiple forms of childhood and household adversity on early educational attainment.
- children exposed to adverse experiences during childhood were less likely, compared to non-exposed peers, to attain the expected level of education at age 6-7 years (KS1) and age 10-11 years (KS2)
- exposure to ACEs increases the chances that children develop into adults with poor economic prospects; contributing to a cycle of hardship that fuels inequalities and potentially locks families into deprivation and ill health across generations.

Introduction

Academic achievement during childhood is influenced by complex interactions between a range of biological, social and environmental factors including the home environment. Mental disorders and alcohol misuse are common in families. Although severe mental illnesses such as schizophrenia and bipolar disorder affect 1–2% of adults in the U.K.,1,2 common mental disorders (CMD), including depression, anxiety, panic, and somatisation, can affect 16% of adults.3 Alcohol misuse is also prevalent, affecting 8% - 10% of adults and a significant proportion also have co-occurring mental disorders.4 We previously estimated that 30% of infants lived with an adult who had a mental disorder5 and up to 30% of children have been reported to live with an adult binge drinker.6

Experience during childhood of long-term or acute stress, for example, due to mental disorders, alcohol related problems or a death in the household have been shown to increase the risk of unplanned hospital admissions during childhood, poorer mental and physical health (increased risk of cancer and cardiovascular disease), as well as negative social outcomes during adulthood (e.g. leaving school without qualifications, unemployment and incarceration).7 The impact of these adverse experiences on education outcomes in school age children is less well-known.

Adverse childhood experiences (ACEs) are thought to elevate glucocorticoid hormones (cortisol), with chronic stress impeding the regulation of stress physiology. For example, children exposed to maternal depression have been shown to have higher levels of salivary cortisol, which could be a mediator in the pathway between chronic stress and lower executive functioning (e.g. working memory).8 Differences in brain activity and hippocampal volume have also been observed based on whether or not children have experienced maltreatment or neglect, but the reasons for this are unclear.9,10 The pre-frontal cortex and executive functions of the brain are known to be sensitive to stress,11 therefore we hypothesised that exposure to adverse childhood experiences impacts negatively on educational attainment during childhood, and contributes to the observed inequalities in education outcomes in children. Understanding the contribution of childhood adversity that may be preventable to the observed social inequalities in education outcomes is important to help us understand the potential impact that interventions that build resilience and mitigate the effects of early adversity can have on later health, well-being, economic activity, and social participation.

In this study we investigated whether or not ACEs were associated with reduced educational attainment at age 7 and 11 years, and the magnitude of these effects, whilst taking in to account the effects of area-level social deprivation, school factors, household composition, sociodemographic and perinatal health indicators using linked administrative datasets. We also explored whether or not children who experienced adversity were more likely to have special education needs requiring learning support.

Methods

Data sources and study design

The Wales Electronic Cohort for Children (WECC) has records for 981 404 children born between 1990 and 2012, for a child or mother resident in Wales12 with information held in the Wales Demographic Service Dataset (a Wales-wide administrative register for all individuals with a general practitioner [GP]). WECC is derived by record-linking deidentified routinely collected health and social datasets described in Table 1, using a unique Anonymised Linking Field (ALF) for each individual. It is accessed through the Secure Anonymised Information Linkage (SAIL) databank at Swansea University, UK.13,14 To enable individuals living in the same household to be anonymously linked, residential anonymised linking fields (RALFs) were created by encrypting individual's addresses for the study period.15,16

Table 1: Data sources

Datasets*	**Data source****
Wales Electronic Cohort for Children	Wales Demographic Service Office of National Statistics birth records Office of National Statistics death records National Community and Child Health database Congenital Anomaly Register and Information Service
Hospital inpatient admission data	Patient Episode Dataset for Wales
General Practice data	General Practice Database
Education data	Pupil Annual School Census National Pupil Database
*Datasets were linked for each child's record using an anonymised linking field based on their NHS number produced by the NHS Wales Informatics Service (NWIS), a NHS trusted third party, with more than 99.85% accuracy.[14] ** data sources are described in supplementary Table 1.	

We included children who had data available for statutory educational assessments in the UK at age 6-7 years and 10-11 years, and for whom adult household members had sufficient GP data to ascertain exposure measures. Exclusions are described in figure 1. To preserve the temporal order of exposure and outcomes in the analyses, only those children who took the statutory assessment at the expected age (using proxy start date of 1st May for each year) were included in the analyses.

The WECC was approved by an independent Information Governance Review Panel. The WECC was judged by the Research Ethics Committee for Wales to be an anonymised research database that does not require ethical review, in line with National Ethics Committee guidance.

Outcomes

Children in Wales have two statutory assessments during compulsory education that is normally taught between ages 5-7 years and 8-11 years17 (two further assessments are taken at age 13-14 and age 15-16 years). In this analysis, the education outcomes were attaining the expected level in statutory assessment at (i) age 6-7 years, Key Stage 1 (KS1) and (ii) age 10-11 years, Key Stage 2 (KS2). KS1 and KS2 are teacher assessments (rather than formal tests) in three core subjects (a language, mathematics and science) where an overall binary measure is derived to indicate whether the expected standard is met or not.

A third outcome about provision of extra learning support for a child at school (Special Educational Need [SEN] provision) was also investigated as an indicator of impaired academic performance. This was coded as a yes/no binary variable, indicating any help received by a child, which may include one to one help or support through external provision to the school (described in UK local educational authority schools as School action, School action plus and Statemented).

Exposures
Exposure was measured (i) between birth to age 6-7 years (KS1) and (ii) between birth to age 10-11 years (KS2). Household members were defined as those living in the same household as the child on their 1st, 5th and 8th birthday.

We defined six measures of childhood adversity. Three of these related to living with an adult household member with any of: (i) serious mental illness diagnosis (e.g. bipolar disorder, schizophrenia);18 (ii) CMD (e.g. depression, anxiety)19 and (iii) an alcohol problem defined by a record of heavy drinking in primary care records20 or an alcohol-related hospital admission21, dating back to 1998. The fourth measure was childhood victimisation defined as an inpatient hospital admission of the child where victimisation was a contributing reason for admission22. The fifth measure was death of a household member and the sixth measure was low family income, defined as eligibility for free school meals in the year the Key Stage assessment was taken.

We used validated algorithms for ascertaining cases of CMD using diagnosis, symptoms and treatments19 and lifetime diagnosis of psychotic disorders18 recorded in General Practice (GP) data sets. Problematic alcohol use among household members was ascertained using a set of GP symptoms, diagnosis and procedures (Read Version 2) codes that we had previously defined20 for current or past heavy alcohol drinking (anything above the recommended limit), alcoholic disease (liver or other), poisoning or treatment evidence and/or any alcohol-related emergency hospital admission during the exposure period. Childhood victimisation was ascertained using a defined set of International Classification of Diseases (ICD)-10 codes in any position of the first consultant episode of an inpatient hospital admission22. For adult household members living with the child at age 1 year, we separated out the presence of alcohol-related problems, CMD or serious mental illness based on whether they were recorded before the birth of the child (pre-birth) or during the first year of life.

Statistical analysis

We used multilevel logistic regression to model exposure to ACEs and (i) not attaining the expected level at KS1and KS2 separately and (ii) receipt of SEN provision. Multilevel modelling was used to include the hierarchical structure of children within schools, so that correlation attributable to schools could be included in the modelling. For each exposure, we estimated odds ratios (ORs) with 95% confidence intervals (CI), adjusting for confounding variables. We used likelihood ratios to test two-way interaction terms between exposures, and between each exposure and each of maternal age, single adult household, and small area deprivation. We repeated the analyses to estimate ORs for any SEN provision allocated in the year the Key Stage assessment was taken, adjusted for maternal and perinatal characteristics.

A Direct Acyclic Graph (DAG)23 was drawn to visualise confounding relationships and obtain a minimal sufficient adjustment set of potential confounders for analyses (figure 2 & 3). We adjusted for household composition (living in a single adult household) and measures of social disadvantage including young maternal age (<18 years) and small-area deprivation (based on Townsend score,24 using the 2001 census for income and address). The Townsend score incorporates unemployment, non-car ownership, non-home ownership and household overcrowding as an area level measure of social deprivation. We chose to use the Townsend score instead of the Welsh Index of Multiple Deprivation (WIMD) because the WIMD includes education and health indicators and therefore we felt would be circular as our exposure and outcome measures were related to health and education domains. Perinatal factors (such as gestational age, academic season of birth, and breastfeeding at birth or 6–8 weeks [when the NHS collects such data]) were adjusted for as the DAG confirmed these factors were on the causal pathway but were not mediators between ACEs and educational attainment. We also adjusted for school factors (number of school moves, average size of school and percentage of children eligible for free school meals) at each Key Stage assessment.

Data were missing for breastfeeding (22% and 42%) and maternal smoking (70% and 80%) in the KS1 and KS2 cohorts respectively. The slightly higher proportions in the KS2 cohort were due to lower data completeness in the earlier years of the cohort. Tabulations by year and unitary authority showed that these could be reasonably assumed to be missing at random, due to organisational and administrative differences in data collection between hospitals. There was little difference between statistical model imputations for these variables, so we concluded that the cohorts were large enough to give sufficient precision. All other variables had less than 5% missing data. Multiple imputation with chained equations25 was used to account for missing data with all covariates and the outcome variable included in the imputation model as described by White and Royston.26 The results of the multilevel modelling were consistent for complete case and the imputed data set, so we present results from the multiply imputed data sets. We used Stata IC (version 13) for statistical analyses.

Role of the funding source

The funders had no role in designing the study, data collection, analysis, or interpretation, or in writing the report. MAB's role in the design, analysis, and writing was independent of the funding from Public Health Wales. The corresponding author had full access to all the data in the study and final responsibility for the decision to submit for publication.

Results

There were 107,479 and 43,648 children in the cohort between 1998 and 2012 who were included in this analysis, with follow-up to 6-7 years (KS1) and 10-11 years (KS2) respectively (figure 1). Sociodemographic characteristics of the children were representative of national population statistics in both cohorts (Supplementary table 2). About 3% of children (n=3,313) were born to a mother who was under 18 years of age at childbirth, and 35,651 (33.2%) had lived in a single adult household (16+ years of age) between birth and age 6-7 years.

Overall 19,508 (18.2%) of children did not attain the expected levels at KS1, 8462 (19.4%) did not attain the expected level at KS2, 27,393 (25.5%) and 11,910 (27.3%) had some SEN provision in the year they took KS1 and 2 (Table 1). A total of 15,553 (14.5%) children aged 1 year lived with an adult who had a history of CMD, and 41,257 (38.4%) children lived with an adult who had a CMD between birth and age 6-7 years (Table 1). Less than 1% of children had lived with an adult who had a serious mental illness. Children who lived with adult household members with CMD had an increased odds of not attaining both KS1 (aOR 1.13 (95% CI 1.09-1.17) and KS2 aOR 1.13 (95%CI 1.07-1.19). A record of serious mental illness in a household adult between birth and KS1 was also associated with increased odds of not attaining KS1 (aOR 1.21 (95% CI 1.02-1.42) but not at KS2 (aOR 0.97 (95% CI 0.79-1.19)). The magnitude of effect for these two exposures at KS1 are similar because the majority of children in this cohort (67.6%) who lived with an adult who had a serious mental illness were also exposed to CMD in the household (Table 2).

Eleven percent of children in the KS1 cohort (n=12,224) and 17.1% (n=7,480) in the KS2 cohort had lived with an adult with an alcohol-related problem; these children had an increased odds for not attaining KS1 (aOR 1.16 (95% CI 1.10-1.22) and KS2 (aOR 1.16 (95% CI 1.09-1.24)), after adjusting for perinatal, sociodemographic, other adverse experiences and school factors.

One percent of children were admitted to hospital during the study period with recorded victimisation, and this group were also less likely to attain KS1 (aOR 1.58 (95% CI 1.37-1.82) and KS2 (aOR 1.88 (95% CI 1.52-2.33)) and more likely to have received SEN provision at KS1 (aOR 1.90 (95% CI 1.66-2.17) and at KS2 (aOR 1.79 (95% CI 1.46-2.20).

About three percent of children in the cohort experienced the death of a household member and this was associated with an increased odds of not attaining KS1 (aOR 1.14 95% CI 1.04-1.25) and KS2 (aOR 1.13 95% CI 1.03-1.25). Low family income (measured as eligibility for a free school meal in the year of taking KS1 or KS2) was also associated with an increased odds of not attaining KS1 (aOR 1.92 95% CI 1.84-2.01) and KS2 (aOR 1.65 95% CI 1.53-1.78).

The effects of socio-economic deprivation were similar on attainment at KS1 and 2, with lower levels of attainment associated with higher levels of social deprivation. Young maternal age and percentage of free school meals in the school attended in the Key Stage year, were both associated with lower educational attainment, although the magnitude of these associations were slightly smaller at KS2 compared with KS1. Children born to older mothers 30+ years were more likely to receive SEN provision at KS1, whereas children born to younger mothers (under 24 years) were more likely to receive this at KS2.

The inclusion of the two-way interaction terms between exposures, and between exposures and each of maternal age, single adult household, and small-area deprivation did not improve the fit of the model to the data at the 5% level. Where present, interactions failed to show consistent, monotonically increasing or decreasing patterns of adjustment to the main effects of interest. Moreover, they did not alter any of our substantive findings, consisting of changes to the third or fourth decimal place. Consequently, interactions were excluded in subsequent modelling and interpretation.

Children who had multiple adversities had substantially increased odds of not attaining the expected level at each educational assessment as shown in figure 4. For example, the odds of not attaining KS1 are 3.59 times higher (aOR 3.59 95%CI 3.25-3.96) for a child who lives in a household in an area with the highest level of

social deprivation, is eligible for free school meals, and lives with an adult who has a CMD and alcohol-related problems, compared with a similar child who lives in a household in an area with the lowest level of social deprivation (Table 4). These data signal a clear need for early identification of this group, and intervention to mitigate the impacts of multiple childhood adversities on education and consequent longer-term social and economic outcomes.

Discussion

This study shows that children exposed to adverse experiences during childhood were less likely, compared to non-exposed peers, to attain the expected level of education at age 6-7 years (KS1) and age 10-11 years (KS2) after controlling for socio-demographic characteristics, perinatal health indicators, household composition and school factors. The magnitude of this association varied according to the type and timing of exposure. For example, exposure during the first year of life to adults who had a history of CMD had a lower magnitude of effect on KS attainment compared to exposure during the years leading up to taking the KS assessments. The observed effect sizes for exposure to mental disorder or alcohol problems in the household were in addition to those observed for living in areas with high levels of social deprivation, suggesting that reducing the prevalence of these household exposures as well as ensuring children who are exposed are identified early and supported appropriately could make a difference to educational outcomes. The effects of these exposures were cumulative, such that children who had multiple exposures had an even higher likelihood of not attaining the expected level at KS assessments. Childhood victimisation and low family income had the biggest effect sizes for not attaining the Key Stages, possibly reflecting the severity of these exposures. Our measure of victimisation was based on hospital admissions only and is therefore likely to underestimate the true impact of victimisation on education outcomes. These findings highlight the importance trauma-informed services for early detection of and intervention for affected children, including the need for additional support to mitigate the future impact on educational outcomes. Death of a household member was also associated with an increased risk of not attaining the expected level at KS assessments. We did not have sufficient data to explore this effect according to the relationship between the child and household member who had died or age at which this occurred. Further work is needed to fully understand how and in what circumstances death in a household impacts on a child's health and well-being.

The relationship between socio-economic deprivation and ACEs is debated in the literature. Our data provides two socio-economic measures (i) area-level deprivation and (ii) individual level eligibility for Free School Meals and we have used this latter measure as a proxy for low family income. We included area-level deprivation as a confounder in our statistical model. A confounder is, by definition, a shared common cause of both exposure and outcome, and consequently is specific to the choice of exposure of interest. Adjusting for a confounder therefore makes implicit causal inferences about hypothetical interventions on the exposure (ACEs) while holding confounders constant. Since our main interest is in the specific ACEs we describe and in the potential for interventions on these ACEs, we considered it entirely appropriate to consider deprivation as a confounder.

Only one previous study has investigated the impact of multiple adverse experiences during childhood on educational outcome.27 This Australian study reported that alcohol use, mental health issues and death of a parent increased the risk of poorer reading attainment at age 8 years but their analyses did not take account of differences in school factors, or examine the cumulative effects of child adversity on educational outcome. Other studies have included wider age ranges of children between 5 to 17 years, reported detrimental effects on educational attainment for household alcohol misuse,27-30 mental health31, or death in the household,32-34 and victimisation of the child.35-37 Most of these studies examined the impact of single adverse exposures and none adjusted for the multiple confounders of deprivation, birth and sociodemographic characteristics, and school factors including school concentration of poverty as we have done in our analysis.

We have previously shown that some ACEs are socio-economically patterned and that these rarely occur in isolation.5,7 Our study therefore adds to the current body of evidence by considering the collective impact of a range of adverse exposures in the household, in addition to socio-economic indicators on educational outcomes.

The key strength of this study is that it measures adverse exposures in the household using administrative and healthcare data. This addresses the limitation of some previous studies which have relied on self-reported data to ascertain exposure during childhood. It also uses data on a wide range of perinatal, sociodemographic and school level data, to take account of the complex relationships between these variables and the association between ACEs and educational outcomes. One limitation is the reliance on coding of administrative data and potential for misspecification of coding, however any misclassification is unlikely to disproportionately affect

one group over another and so is unlikely to have created a bias in any particular direction. We did not have data on parental education or IQ (as a proxy for variation in school engagement) nor on contact with social care and therefore could not explore the role of these variables. Our data showed that 27% of children had SEN provision however we did not have sufficient data to explore any unmet need or the appropriateness of this provision for individual children. Further research is needed to explore how SEN provision is implemented, whether or not there is appropriate SEN provision to support young children and how this is accessed.

At a population level, our study demonstrates how the educational potential of many children may not be achieved due to exposure to adversity in childhood. Although the distribution of ACEs are socially patterned, our results suggest that the impacts of ACEs on educational outcomes are in addition to those related to social deprivation. Thus, a combination of poverty and childhood exposure to household mental disorders and alcohol-related problems increases the likelihood of failing the basic educational tests in language and maths by over 350% for children living in the most compared to least deprived areas.

Critically, a poor start in education has been strongly linked with poorer educational outcomes across all schooling years, poorer employment prospects and consequently a poor economic outlook across the life course.7,38-40 Consequently, exposure to ACEs increases the chances that children develop into adults with poor economic prospects; contributing to a cycle of hardship that fuels inequalities and potentially locks families into deprivation and ill health across generations. There are already a range of evidence-based interventions that provide parent and caregiver support,41,42 pre-school enrichment43,44 and increasingly, trauma-informed educational services.45,46 It is no longer a lack of effective interventions or sound economic arguments that is preventing safe and secure childhoods. It is only a question of the political investment necessary to ensure subsequent generations achieve their full potential for themselves and for the prosperity of communities in which they live.

In conclusion our study shows that children living with adults who have mental disorders or alcohol problems, who have experienced victimisation or experienced a death in the family are at increased risk of not achieving their educational potential. As these experiences are relatively common, it is important that appropriate conversations are initiated when affected children come in to contact with health, education and social care services, and that relevant information is shared between health and care services and schools to facilitate a coordinated approach to tackle adverse household exposures such as alcohol misuse and family violence as early as possible, whilst supporting affected families and children. It is also important that schools are adequately resourced to provide the additional support needed for children from affected families to reduce their risk of lower educational outcomes and help them to fulfil their educational potential, and subsequent economic and social participation.

Author statement

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Table 1: Characteristics of adverse experiences in childhood, family diversity, socio-demographics.

		Key Stage 1 cohort						Key Stage 2 cohort					
		Total		Not attained KS1		Special Education Need provided at		Total		Not attained KS2		Special Education Need provided at	
		N=107,479		n=19,508 n (%)		n=27,393 n (%)		N=43,648		n=8,462 n (%)		n=11,910 n (%)	
Adverse experiences in childhood													
Common mental disorder GP code for a household member													
before birth of child	No	91926	(85.5)	15987	(17.4)	22431	(24.4)	40602	(93.0)	7770	(19.1)	10897	(26.8)
	Yes	15553	(14.5)	3521	(22.6)	4962	(31.9)	3046	(7.0)	692	(22.7)	1013	(33.3)
birth to Key Stage	No	66222	(61.6)	10735	(16.2)	15290	(23.1)	23001	(52.7)	3898	(16.9)	5657	(24.6)
	Yes	41257	(38.4)	8773	(21.3)	12103	(29.3)	20647	(47.3)	4564	(22.1)	6253	(30.3)
Serious mental illness GP code for a household member													
before birth of child	No	107051	(99.6)	19399	(18.1)	27230	(25.4)	43568	(99.8)	8446	(19.4)	11881	(27.3)
	Yes	428	(0.4)	109	(25.5)	163	(38.1)	80	(0.2)	16	(20.0)	29	(36.3)
birth to Key Stage	No	106550	(99.1)	19247	(18.1)	27052	(25.4)	43074	(98.7)	8308	(19.3)	11703	(27.2)
	Yes	929	(0.9)	261	(28.1)	341	(36.7)	574	(1.3)	154	(26.8)	207	(36.1)
Alcohol problem GP code for a household member													
before birth of child	No	101695	(94.6)	17853	(17.6)	25225	(24.8)	42487	(97.3)	8130	(19.1)	11453	(27.0)
	Yes	5784	(5.4)	1655	(28.6)	2168	(37.5)	1161	(2.7)	332	(28.6)	457	(39.4)
Alcohol problem GP code or alcohol-related hospital admission for a household member													
birth to Key Stage	No	95255	(88.6)	16198	(17.0)	23035	(24.2)	36168	(82.9)	6379	(17.6)	9222	(25.5)
	Yes	12224	(11.4)	3310	(27.1)	4358	(35.7)	7480	(17.1)	2083	(27.8)	2688	(35.9)
Victimisation hospital admission code from birth to Key Stage	No	106407	(99.0)	19095	(17.9)	26847	(25.2)	43284	(99.2)	8316	(19.2)	11730	(27.1)
	Yes	1072	(1.0)	413	(38.5)	546	(50.9)	364	(0.8)	146	(40.1)	180	(49.5)
Household member died from 1 year to Key Stage	No	104015	(96.8)	18726	(18.0)	26312	(25.3)	42223	(96.7)	8107	(19.2)	11431	(27.1)
	Yes	3464	(3.2)	782	(22.6)	1081	(31.2)	1425	(3.3)	355	(24.9)	479	(33.6)
Free school meal in KS1 year	No	87206	(81.1)	12536	(14.4)	18730	(21.5)	36048	(82.6)	5673	(15.7)	8506	(23.6)
	Yes	20273	(18.9)	6972	(34.4)	8663	(42.7)	7600	(17.4)	2789	(36.7)	3404	(44.8)
Free school meal in KS2 year	No	-	-	-	-	-	-	35908	(82.3)	5608	(15.6)	8499	(23.7)
	Yes	-	-	-	-	-	-	7740	(17.7)	2854	(36.9)	3411	(44.1)
Family characteristics													
Ever in a single parent household from birth to 5 or 8 years	No	71828	(66.8)	11878	(16.5)	16929	(23.6)	26664	(61.1)	4591	(17.2)	6643	(24.9)
	Yes	35651	(33.2)	7630	(21.4)	10464	(29.4)	16984	(38.9)	3871	(22.8)	5267	(31.0)

†Any code of school action, school action plus or statemented.

Table 1: Characteristics of household adverse experiences, social disadvantage, socio-demographics (cont).

		Key Stage 1 cohort						Key Stage 2 cohort					
		Total		Not attained KS1		Special Education Need provided at KS1†		Total		Not attained KS2		Special Education Need provided at KS2†	
		N=107,479		n=19,508 n (%)		n=27,393 n (%)		N=43,648		n=8,462 n (%)		n=11,910 n (%)	
Maternal age at childbirth	<18	3313	(3.1)	1001	(30.2)	1289	(24.1)	1461	(3.3)	431	(29.5)	569	(38.9)
	18-24	30226	(28.1)	7150	(23.7)	9683	(20.3)	11976	(27.4)	2972	(24.8)	3964	(33.1)
	25-29 years old	29782	(27.7)	5014	(16.8)	7169	(22.1)	13017	(29.8)	2397	(18.4)	3378	(26.0)
	30-34	29095	(27.1)	4032	(13.9)	5910	(38.9)	11691	(26.8)	1767	(15.1)	2665	(22.8)
	35+	14998	(14.0)	2289	(15.3)	3318	(32.0)	5470	(12.5)	881	(16.1)	1321	(24.1)
	Missing data	65	(0.1)	22	(33.8)	24	(36.9)	33	(0.1)	14	(42.4)	13	(39.4)
Maternal cigarette smoking at booking in	No	24634	(22.9)	3646	(14.8)	5625	(22.8)	6375	(14.6)	991	(15.5)	1555	(24.4)
	Yes	8163	(7.6)	2203	(27.0)	3004	(36.8)	2366	(5.4)	627	(26.5)	904	(38.2)
	Missing data	74682	(69.5)	13659	(18.3)	18764	(25.1)	34907	(80.0)	6844	(19.6)	9451	(27.1)
Parity	No	46311	(43.1)	7150	(15.4)	10347	(22.3)	18660	(42.8)	3164	(17.0)	4560	(24.4)
	Yes	60935	(56.7)	12318	(20.2)	16972	(27.9)	24920	(57.1)	5287	(21.2)	7331	(29.4)
	Missing data	233	(0.2)	40	(17.2)	74	(31.8)	68	(0.2)	11	(16.2)	19	(27.9)
Area level measure of social deprivation													
Townsend deprivation quintile at birth or first 4 months	1 - least deprived	18383	(17.1)	1869	(10.2)	3027	(16.5)	7180	(16.4)	811	(11.3)	1257	(17.5)
	2	19475	(18.1)	2723	(14.0)	3983	(20.5)	7912	(18.1)	1233	(15.6)	1908	(24.1)
	3	21090	(19.6)	3681	(17.5)	5217	(24.7)	8582	(19.7)	1549	(18.0)	2319	(27.0)
	4	22126	(20.6)	4418	(20.0)	6246	(28.2)	8932	(20.5)	1922	(21.5)	2665	(29.8)
	5 - Most deprived	26078	(24.3)	6762	(25.9)	8851	(33.9)	10820	(24.8)	2900	(26.8)	3705	(34.2)
	Missing data	327	(0.3)	55	(16.8)	69	(21.1)	222	(0.5)	47	(21.2)	56	(25.2)

†Any code of school action, school action plus or statemented.

Table 1: Characteristics of birth (cont).

		Key Stage 1 cohort						Key Stage 2 cohort					
		Total		Not attained KS1		Special Education Need provided at KS1†		Total		Not attained KS2		Special Education Need provided at KS2†	
		N=107,479		n=19,508 n (%)		n=27,393 n (%)		N=43,648		n=8,462 n (%)		n=11,910 n (%)	
Birth characteristics													
Sex	Male	55234	(51.4)	12423	(22.5)	17815	(32.3)	22249	(51.0)	5199	(23.4)	7615	(34.2)
	Female	52245	(48.6)	7085	(13.6)	9578	(18.3)	21399	(49.0)	3263	(15.2)	4295	(20.1)
Gestational age at birth	24 - < 28 weeks: extremely preterm	263	(0.2)	117	(44.5)	152	(57.8)	104	(0.2)	49	(47.1)	56	(53.8)
	28 - < 33 weeks: v preterm	1379	(1.3)	407	(29.5)	561	(40.7)	549	(1.3)	163	(29.7)	226	(41.2)
	33 - < 37 weeks: moderately preterm	6060	(5.6)	1393	(23.0)	1907	(31.5)	2370	(5.4)	555	(23.4)	769	(32.4)
	37+ weeks: term	93817	(87.3)	16403	(17.5)	23225	(24.8)	37832	(86.7)	7132	(18.9)	10107	(26.7)
	Missing data	5960	(5.5)	1188	(19.9)	1548	(26.0)	2793	(6.4)	563	(20.2)	752	(26.9)
Small for gestational age	No	91145	(84.8)	15706	(17.2)	22467	(24.6)	36646	(84.0)	6799	(18.6)	9643	(26.3)
	Yes	9836	(9.2)	2491	(25.3)	3206	(32.6)	3960	(9.1)	1053	(26.6)	1436	(36.3)
	Missing data	6498	(6.0)	1311	(20.2)	1720	(26.5)	3042	(7.0)	610	(20.1)	831	(27.3)
Breastfeeding at birth or 6-8 weeks	No	40191	(37.4)	9043	(22.5)	12295	(30.6)	13064	(29.9)	3111	(23.8)	4083	(31.3)
	Yes	43664	(40.6)	6136	(14.1)	9177	(21.0)	12173	(27.9)	1841	(15.1)	2835	(23.3)
	Missing data	23624	(22.0)	4329	(18.3)	5921	(25.1)	18411	(42.2)	3510	(19.1)	4992	(27.1)
Congenital anomalies	None	102339	(95.2)	18087	(17.7)	25406	(24.8)	41514	(95.1)	7861	(18.9)	11056	(26.6)
	Major/minor	5140	(4.8)	1421	(27.7)	1987	(38.7)	2134	(4.9)	601	(28.2)	854	(40.9)
Academic season of birth	Sept-Dec	33044	(30.7)	4379	(13.3)	6837	(20.7)	11659	(26.7)	1730	(14.8)	2833	(24.3)
	Jan-April	36522	(34.0)	6485	(17.8)	9050	(24.8)	15953	(36.5)	3108	(19.5)	4331	(27.1)
	May-August	37913	(35.3)	8644	(22.8)	11506	(30.3)	16036	(36.7)	3624	(22.6)	4746	(29.6)

†Any code of school action, school action plus or statemented.

Table 1: Characteristics at school (cont).

		Key Stage 1 cohort						Key Stage 2 cohort					
		Total		Not attained KS1		Special Education Need provided at		Total		Not attained KS2		Special Education Need provided at	
		N=107,479		n=19,508 n (%)		n=27,393 n (%)		N=43,648		n=8,462 n (%)		n=11,910 n (%)	
School factors													
School moves start school to Key Stage 1	0	101580	(94.5)	17743	(17.5)	25383	(25.0)	41532	(95.2)	7812	(18.8)	11095	(26.7)
	1+	5899	(5.5)	1765	(29.9)	2010	(34.1)	2116	(4.8)	650	(30.7)	815	(38.5)
School moves from KS1 to KS2	0	-	-	-	-	-	-	31554	(72.3)	5447	(17.3)	8144	(25.8)
	1	-	-	-	-	-	-	8883	(20.4)	2203	(24.8)	2776	(31.3)
	2	-	-	-	-	-	-	3003	(6.9)	732	(24.4)	905	(30.1)
	3+	-	-	-	-	-	-	208	(0.5)	80	(38.5)	85	(40.9)
School average size at Key Stage^	> 0 - 100 pupils	10150	(9.4)	2076	(20.5)	2425	(23.9)	3967	(9.1)	793	(20.0)	1222	(30.8)
	> 100 - 150 pupils	12175	(11.3)	2679	(22.0)	3589	(29.5)	4584	(10.5)	1039	(22.7)	1453	(31.7)
	>150 - 200 pupils	18875	(17.6)	3632	(19.2)	4975	(26.4)	7310	(16.7)	1526	(20.9)	2120	(29.0)
	> 200 - 300 pupils	32621	(30.4)	5816	(17.8)	8674	(26.6)	12956	(29.7)	2561	(19.8)	3502	(27.0)
	> 300 pupils	33658	(31.3)	5305	(15.8)	7730	(23.0)	14831	(34.0)	2543	(17.1)	3613	(24.4)
School mean percent of children eligible for free school meal at Key Stage^	<=5%	16316	(15.2)	1630	(10.0)	2531	(15.5)	5808	(13.3)	649	(11.2)	1109	(19.1)
	>5-10	21668	(20.2)	2752	(12.7)	4110	(19.0)	7860	(18.0)	1106	(14.1)	1714	(21.8)
	>10-15	19312	(18.0)	3163	(16.4)	4277	(22.1)	6960	(15.9)	1182	(17.0)	1731	(24.9)
	>15-20	15647	(14.6)	***	(18.1)	4165	(26.6)	6427	(14.7)	1161	(18.1)	1698	(26.4)
	>20-30	18799	(17.5)	4117	(21.9)	6018	(32.0)	8409	(19.3)	1828	(21.7)	2501	(29.7)
	>30	15728	(14.6)	5013	(31.9)	6287	(40.0)	8183	(18.7)	2535	(31.0)	3156	(38.6)
	Missing data	9	(0.01)	<5	(33.3)	5	(55.6)	-	-	-	-	-	-
Year take Key Stage	2005	8174	(7.6)	1702	(20.8)	2110	(25.8)	-	-	-	-	-	-
	2006	12475	(11.6)	2351	(18.9)	3019	(24.2)	-	-	-	-	-	-
	2007	12841	(12.0)	2439	(19.0)	3248	(25.3)	-	-	-	-	-	-
	2008	13742	(12.8)	2558	(18.6)	3645	(26.5)	-	-	-	-	-	-
	2009	14236	(13.3)	2518	(17.7)	3662	(25.7)	7641	(17.5)	1806	(23.6)	2068	(27.1)
	2010	14666	(13.7)	2552	(17.4)	3705	(25.3)	11523	(26.4)	2377	(20.6)	3075	(26.7)
	2011	14980	(14.0)	2376	(15.9)	3750	(25.0)	11827	(27.1)	2235	(18.9)	3211	(27.2)
	2012	16365	(15.2)	3012	(18.4)	4254	(26.0)	12657	(29.0)	2044	(16.2)	3556	(28.1)

†Any of school action, school action plus, statemented; ^For years take Key Stage in cohorts; ***raw count not shown for to prevent identifiability for category with less than 5 counts.

Table 2: Multilevel logistic regressions of adverse experiences in childhood and education performance at age 6-7 years in Key Stage 1 attainment, and Special Educational Need provision.

		Key Stage 1 cohort (N=107,479)											
		Not attained KS1						Special Education Need provided KS1†					
		Univariable OR (95% CI)			Multivariable OR (95% CI)*			Univariable OR (95% CI)			Multivariable OR (95% CI)*		
Adverse experiences in the household													
Common mental disorder GP code for a household member before birth of child	No	1.00			1.00			1.00			1.00		
	Yes	1.35	1.29	1.41	1.08	1.03	1.14	1.40	1.35	1.45	1.11	1.06	1.16
Common mental disorder GP code for a household member from birth to Key Stage	No	1.00			1.00			1.00			1.00		
	Yes	1.32	1.28	1.37	1.13	1.09	1.17	1.32	1.28	1.36	1.14	1.10	1.18
Serious mental illness GP code for a household member before birth of child	No	1.00			1.00			1.00			1.00		
	Yes	1.41	1.13	1.77	0.92	0.72	1.18	1.74	1.42	2.13	1.15	0.92	1.44
Serious mental illness GP code for a household member from birth to Key Stage	No	1.00			1.00			1.00			1.00		
	Yes	1.66	1.42	1.93	1.21	1.02	1.42	1.62	1.41	1.86	1.20	1.03	1.40
Alcohol problem GP code for a household member before birth of child	No	1.00			1.00			1.00			1.00		
	Yes	1.70	1.60	1.81	1.17	1.09	1.25	1.67	1.58	1.77	1.14	1.07	1.22
Alcohol problem GP code or alcohol-related hospital admission for a household member from birth to Key	No	1.00			1.00			1.00			1.00		
	Yes	1.63	1.56	1.71	1.16	1.10	1.22	1.57	1.51	1.64	1.18	1.12	1.23
Victimisation hospital admission code from birth to Key Stage	No	1.00			1.00			1.00			1.00		
	Yes	2.49	2.18	2.84	1.58	1.37	1.82	2.78	2.45	3.16	1.90	1.66	2.17
Household member died from 1 year to Key Stage	No	1.00			1.00			1.00			1.00		
	Yes	1.27	1.17	1.39	1.14	1.04	1.25	1.32	1.23	1.43	1.21	1.11	1.31
Free school meal in year when take KS1	No	1.00			1.00			1.00			1.00		
	Yes	2.70	2.60	2.81	1.92	1.84	2.01	2.41	2.32	2.49	1.77	1.70	1.84
Family characteristics													
Ever in a single parent household from birth to 5 or 8 years	No	1.00			1.00			1.00			1.00		
	Yes	1.26	1.22	1.31	1.05	1.01	1.09	1.25	1.21	1.29	1.07	1.04	1.11
Maternal age at childbirth	<18	1.84	1.69	2.00	1.56	1.42	1.72	1.72	1.59	1.86	1.52	1.39	1.66
	18-24	1.40	1.34	1.46	1.23	1.18	1.29	1.36	1.31	1.42	1.22	1.18	1.28
	25-29 years old	1.00			1.00			1.00			1.00		
	30-34	0.84	0.80	0.88	0.90	0.86	0.95	0.84	0.81	0.88	0.88	0.85	0.92
	35+	0.95	0.90	1.00	1.00	0.95	1.06	0.96	0.92	1.01	0.99	0.94	1.04
Maternal cigarette smoking at booking in	No	1.00			1.00			1.00			1.00		
	Yes	1.93	1.79	2.08	1.34	1.22	1.47	1.65	1.57	1.74	1.19	1.11	1.28
Parity	No	1.00			1.00			1.00			1.00		
	Yes	1.35	1.31	1.40	1.47	1.41	1.53	1.32	1.28	1.36	1.44	1.40	1.49

*adjusted for variables in the table significant in univariable regression at the 5% level and confounders visualised in DAGs, sex, gestational age at birth, small for gestational age (<10th centile), parity, congenital anomalies, academic season of birth, school moves from start school to KS1, school average size at Key Stage, school mean percent of children eligible for free school meals at Key Stage, Year take Key Stage; OR=odds ratio;
†Any of school action (SA), SA plus, statemented.

Table 2: Multilevel logistic regressions of adverse experiences in childhood and education performance at age 6-7 years in Key Stage 1 attainment, and Special Educational Need provision (cont).

		Key Stage 1 cohort (N=107,479)											
		Not attained KS1						Special Education Need provided KS1†					
		Univariable OR (95% CI)			Multivariable OR (95% CI)*			Univariable OR (95% CI)			Multivariable OR (95% CI)*		
Area/School measures of social deprivation													
Townsend deprivation quintile at birth or first 4 months	1 - least deprived	1.00			1.00			1.00			1.00		
	2	1.28	1.19	1.37	1.13	1.05	1.21	1.21	1.14	1.28	1.10	1.04	1.17
	3	1.56	1.46	1.66	1.22	1.14	1.31	1.46	1.38	1.54	1.20	1.13	1.27
	4	1.84	1.72	1.96	1.32	1.23	1.41	1.72	1.63	1.82	1.31	1.23	1.39
	5 - Most deprived	2.37	2.23	2.53	1.43	1.33	1.53	2.11	1.99	2.22	1.35	1.27	1.43
School mean concentration of children eligible for fresh school meanls at KS1	≤5%	1.00			1.00			1.00			1.00		
	>5-10	1.21	1.10	1.35	1.10	0.99	1.23	1.32	1.20	1.45	1.16	1.05	1.29
	>10-15	1.63	1.48	1.81	1.30	1.17	1.45	1.62	1.48	1.79	1.28	1.15	1.42
	>15-20	1.89	1.70	2.10	1.33	1.19	1.48	1.97	1.79	2.18	1.40	1.26	1.56
	>20-30	2.27	2.05	2.51	1.40	1.26	1.55	2.65	2.42	2.90	1.71	1.54	1.89
	>30	4.09	3.71	4.51	1.93	1.73	2.15	4.11	3.75	4.51	2.09	1.88	2.32

*adjusted for variables in the table significant in univariable regression at the 5% level and confounders visualised in DAGs, sex, gestational age at birth, small for gestational age (<10^{th} centile), parity, congenital anomalies, academic season of birth, school moves from start school to KS1, school average size at Key Stage, Year take Key Stage; OR=odds ratio;

†Any of school action (SA), SA plus,statemented.

Table 3: Multilevel logistic regression of adverse experiences in childhood and education performance at age 10-11 years in Key Stage 2 attainment, and Special Educational Need provision.

		Key Stage 2 cohort (N=43,648)											
		Not attained KS2						Special Education Need provided KS2†					
		Univariable			Multivariable			Univariable			Multivariable		
Adverse experiences in the household													
Common mental disorder GP code for a household member	No	1.00			1.00			1.00			1.00		
before birth of child	Yes	1.19	1.09	1.31	0.99	0.89	1.09	1.33	1.23	1.45	1.02	0.94	1.12
Common mental disorder GP code for a household member	No	1.00			1.00			1.00			1.00		
from birth to Key Stage	Yes	1.34	1.27	1.41	1.13	1.07	1.19	1.29	1.23	1.35	1.11	1.06	1.16
Serious mental illness GP code for a household member before	No	1.00			1.00			1.00			1.00		
birth of child	Yes	1.02	0.58	1.81	0.79	0.43	1.45	1.51	0.94	2.43	1.06	0.63	1.76
Serious mental illness GP code for a household member from	No	1.00			1.00			1.00			1.00		
birth to Key Stage	Yes	1.36	1.12	1.66	0.97	0.79	1.19	1.39	1.16	1.67	1.05	0.87	1.27
Alcohol problem GP code for a household member before	No	1.00			1.00			1.00			1.00		
birth of child	Yes	1.54	1.34	1.77	1.13	0.97	1.31	1.65	1.46	1.88	1.13	0.98	1.29
Alcohol problem GP code or alcohol-related hospital	No	1.00			1.00			1.00			1.00		
admission for a household member from birth to Key Stage	Yes	1.65	1.55	1.75	1.16	1.09	1.24	1.52	1.44	1.61	1.11	1.05	1.19
Victimisation hospital admission code from birth to Key Stage	No	1.00			1.00			1.00			1.00		
	Yes	2.79	2.29	3.41	1.88	1.52	2.33	2.39	1.92	2.97	1.79	1.46	2.20
Household member died from 1 year to Key Stage	No	1.00			1.00			1.00			1.00		
	Yes	1.32	1.20	1.45	1.13	1.03	1.25	1.30	1.15	1.46	1.13	1.03	1.24
Free school meal in year when take KS1	No	1.00			1.00			1.00			1.00		
	Yes	2.78	2.62	2.95	1.51	1.40	1.63	2.41	2.28	2.55	1.50	1.40	1.62
Free school meal in year when take KS2	No	1.00			1.00			1.00			1.00		
	Yes	2.82	2.66	2.99	1.65	1.53	1.78	2.33	2.20	2.46	1.40	1.30	1.51
Family characteristics													
Ever in a single parent household from birth to 5 or 8 years	No	1.00			1.00			1.00			1.00		
	Yes	1.32	1.26	1.39	1.04	0.99	1.10	1.26	1.20	1.32	1.05	1.00	1.11
Maternal age at childbirth	<18	1.62	1.43	1.84	1.30	1.13	1.49	1.64	1.46	1.85	1.42	1.24	1.61
	18-24	1.36	1.27	1.45	1.18	1.10	1.26	1.34	1.26	1.42	1.20	1.12	1.27
	25-29 years old	1.00			1.00			1.00			1.00		
	30-34	0.83	0.77	0.89	0.90	0.83	0.97	0.88	0.83	0.94	0.93	0.87	0.99
	35+	0.89	0.82	0.98	0.95	0.86	1.04	0.95	0.88	1.02	0.96	0.89	1.05
Maternal cigarette smoking at booking in	No	1.00			1.00			1.00			1.00		
	Yes	1.73	1.62	1.85	1.18	1.09	1.28	1.81	1.63	2.01	1.32	1.13	1.55
Parity	No	1.00			1.00			1.00			1.00		
	Yes	1.29	1.23	1.36	1.37	1.29	1.46	1.26	1.21	1.32	1.36	1.29	1.43

*adjusted for variables in the table significant in univariable regression at the 5% level and confounders visualised in DAGs, sex, gestational age at birth, small for gestational age (<10th centile), parity, congenital anomalies, academic season of birth, school moves from start school to KS1, school average size at Key Stage, school mean percent of children eligible for free school meals at Key Stage, Year take Key Stage; OR=odds ratio; †Any of school action (SA), SA plus,statemented.

Table 3: Multilevel logistic regression of adverse experiences in childhood and education performance at age 10-11 years in Key Stage 2 attainment, and Special Educational Need provision (cont).

		Key Stage 2 cohort (N=43,648)											
		Not attained KS2						Special Education Need provided KS2†					
		Univariable OR (95% CI)			Multivariable OR (95% CI)*			Univariable OR (95% CI)			Multivariable OR (95% CI)*		
Area/School measures of social deprivation													
Townsend deprivation quintile at birth or first 4 months	1 - least deprived	1.00			1.00			1.00			1.00		
	2	1.38	1.24	1.53	1.23	1.11	1.37	1.35	1.23	1.47	1.22	1.11	1.34
	3	1.55	1.40	1.72	1.23	1.11	1.37	1.50	1.37	1.63	1.25	1.14	1.37
	4	1.93	1.75	2.13	1.38	1.25	1.54	1.74	1.60	1.90	1.34	1.22	1.46
	5 - Most deprived	2.40	2.18	2.65	1.45	1.31	1.61	2.03	1.86	2.21	1.35	1.23	1.48
School mean concentration of children eligible for	≤5%	1.00			1.00			1.00			1.00		
	>5-10	1.24	1.06	1.45	1.11	0.94	1.30	1.10	0.96	1.27	1.06	0.91	1.22
	>10-15	1.58	1.35	1.84	1.21	1.03	1.42	1.32	1.14	1.53	1.11	0.96	1.30
	>15-20	1.69	1.44	1.99	1.18	1.00	1.39	1.46	1.26	1.70	1.13	0.97	1.33
	>20-30	2.20	1.90	2.56	1.26	1.07	1.48	1.74	1.52	2.00	1.15	0.99	1.34
	>30	3.89	3.36	4.49	1.69	1.44	1.98	2.79	2.43	3.19	1.44	1.24	1.68

*adjusted for variables in the table significant in univariable regression at the 5% level and confounders visualised in DAGs, sex, gestational age at birth, small for gestational age (<10th centile), parity, congenital anomalies, academic season of birth, school moves from start school to KS1, school average size at Key Stage, school mean percent of children eligible for free school meals at Key Stage, Year take Key Stage; OR=odds ratio; †Any of school action (SA), SA plus,statemented.

Table 4: Likelihood of poor school performance associated with combinations of exposures and soci-demographic characteristics (based on linear combinations of adjusted model in Tables 2).

Reference category: Least deprived quintile of area-level deprivation, not eligible for free school meals in year preceding KS1 assessment (proxy start date 1st May), never exposed to child adversity measured, maternal age at childbirth between 25-29 years old, ≤5% mean of number of children eligible for free school meals in school when take the Key Stage 1 assessment.	**Not attained KS1 at age 6-7 years**		**Received SEN provision at age 6-7 years**	
	OR[a]	**(95% CI)**	**OR[a]**	**(95% CI)**
Household member with common mental disorder[b] AND household member with alcohol problems[b]	1.31	(1.23-1.39)	1.34	(1.27-1.41)
Most deprived quintile at birth/first 4 months AND eligible for free school meals in year preceding KS1 assessment AND household member with common mental disorder[b] AND household member with alcohol problems[b]	3.59	(3.25-3.96)	3.20	(2.94-3.49)
Most deprived quintile at birth/first 4 months AND eligible for free school meals in year preceding KS1 assessment AND household member with common mental disorder[b] AND household member with alcohol problems[b] AND victimisation	5.67	(4.80-6.71)	6.08	(5.19-7.12)

a=Odds ratio; b=between child's birth and age 6-7 years (KS1); KS1=Key Stage 1; SEN=Special Educational Need provision.

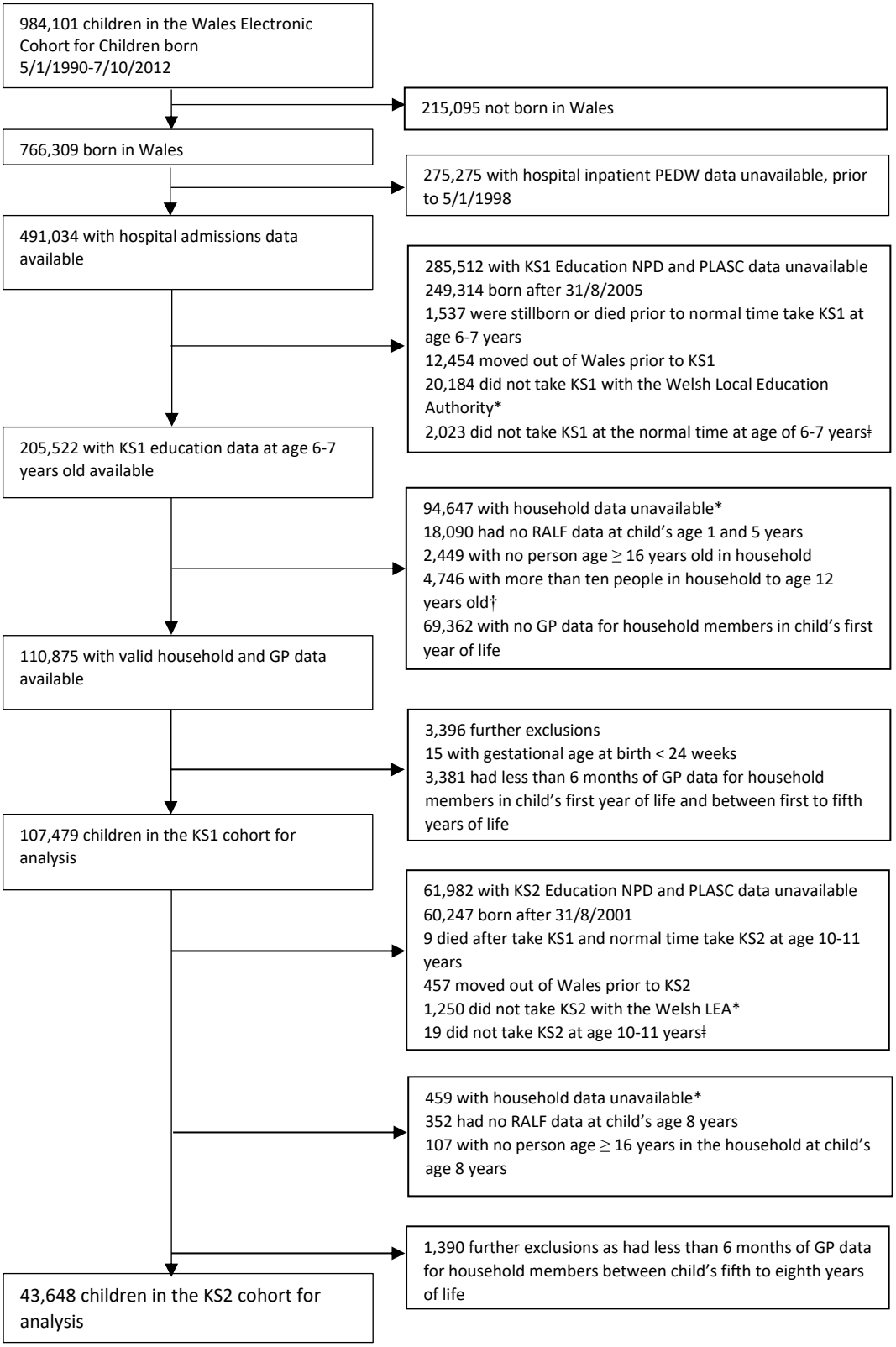

Figure 1: Anonymised participant selection for analyses. PEDW=Patient Episode Database Wales, RALF=Residential Anonymous Linking Field, GP=General Practice, KS=Key Stage, NPD=National Pupil Database, PLASC=Pupil Level Annual School Census, LEA=Local Education Authority. *private schools, severely disabled children who are not catered for by Special Educational Needs provision in the LEA school system; ** those outside administrative systems e.g. travellers; ǂ to adhere to no overlap between exposure and outcome time windows. † so it can be assumed to be a household unit.

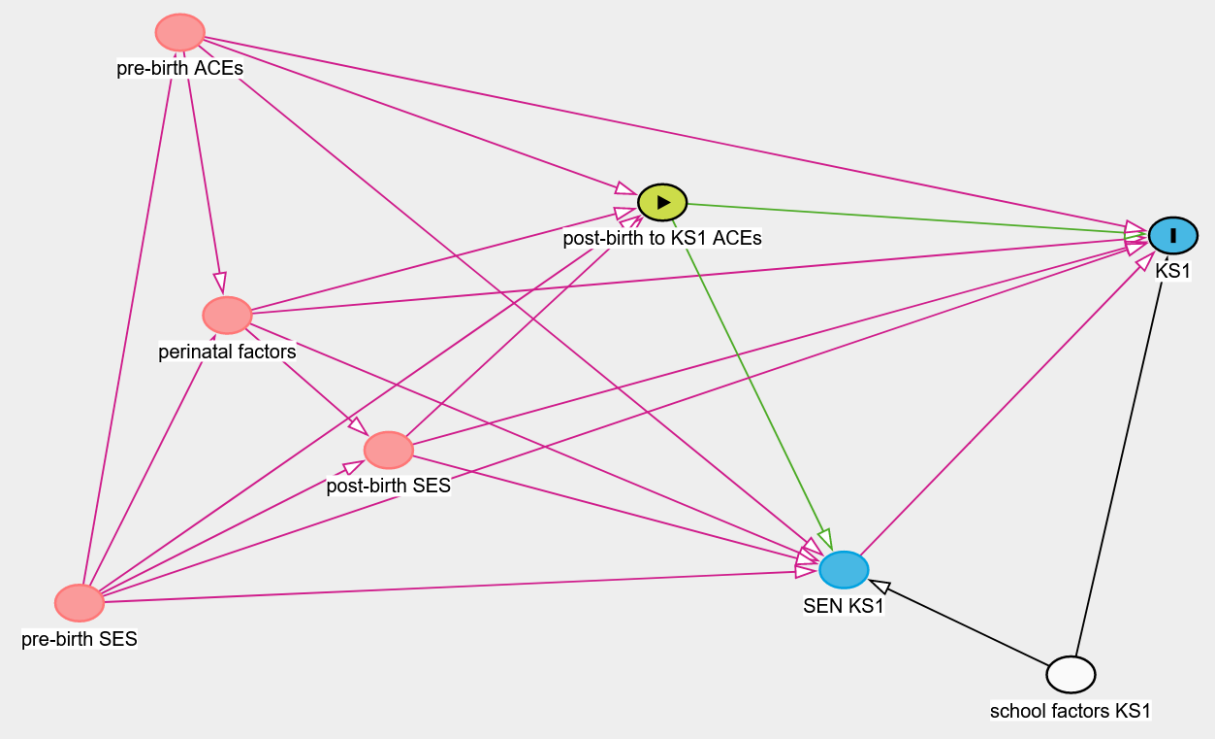

Figure 2: Directed acyclic graph of exposure to post-birth adverse childhood experiences and KS1 attainment outcome. The minimal sufficient adjustment set for total effects analysis was pre-birth SES and school factors at KS1. ACE=adverse childhood experience; SES=Socio-economic status; SEN=Special Educational Needs provision; KS=Key Stage.

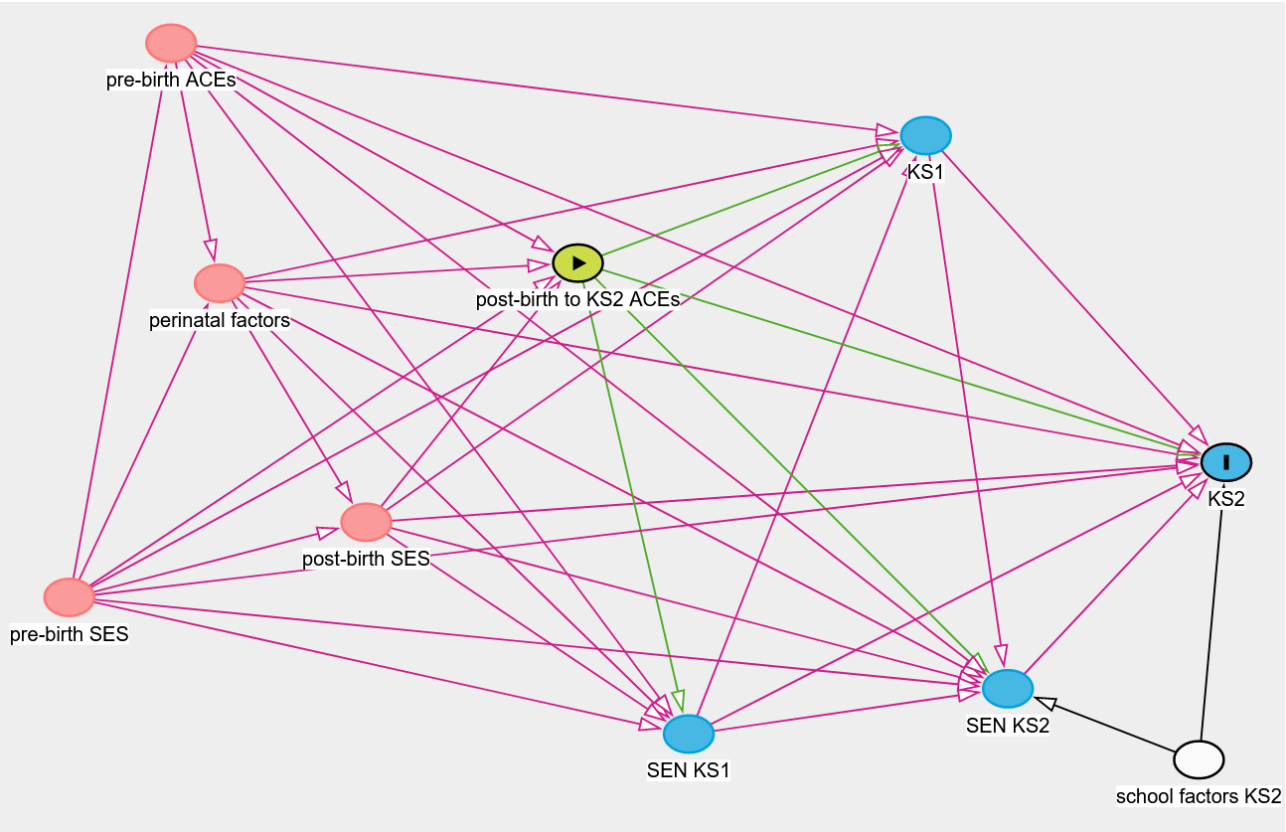

Figure 3: Directed acyclic graph of exposure to post-birth adverse childhood experiences and KS2 attainment outcome. The minimal sufficient adjustment set for total effects analysis was pre-birth ACEs, prebirth SES, perinatal factors, post-birth SES and school factors at KS2.

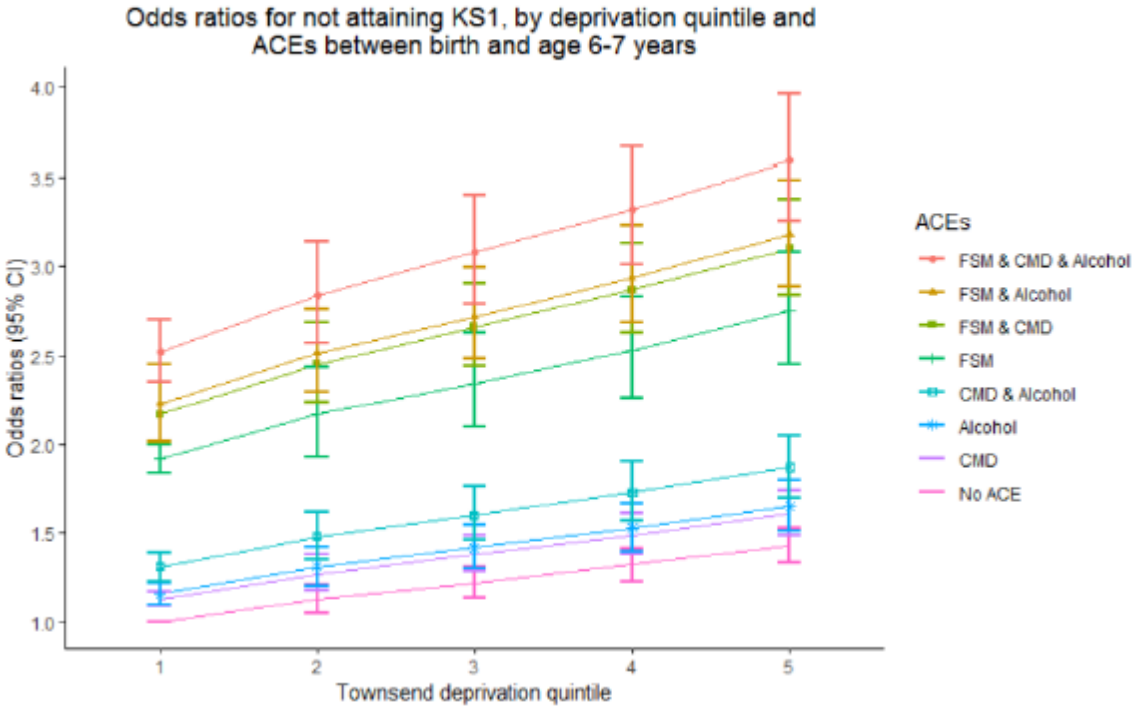

Figure 4: Likelihood of not attaining KS1 associated with combinations of exposures and sociodemographic characteristics (based on linear combinations of adjusted model in Tables 2).
ACE=adverse childhood experience; CMD=household common mental disorder;
Alcohol=household alcohol problem; FSM=free school meals eligible in year preceding KS1 assessment (proxy start date 1st May).

Appendix: Supplementary tables

Supplementary Table 1: WECC Data sources

Data source	Description
Public Health Birth files from the Office for National Statistics (ONSB) - from 2003	Data on all births in Wales or to mothers who are usually resident in Wales
Public Health Mortality Files from the Office for National Statistics (ONSM) - from 2002	Data on all deaths in Wales or of individuals who are usually resident in Wales
Welsh Demographic Service (previously the National Health Service Administrative Register) – electronic data from 1990	Data from contact with any national health services, demographic details include name, address, date of birth, general practice and NHS number (the maintained list is used to create the Anonymised Linking Field (ALF) and the Residential Anonymised Linking Field (RALF))
National Community Child Health Database (NCCHD) - from 1987	A national database of all children resident in Wales or born in a Welsh hospital, containing data collected at birth such as parity, mode of delivery, gestation, birth weight, gender, breastfeeding, and Apgar Score
Patient Episode Dataset for Wales (PEDW) - from 1998	Demographic and clinical data on all inpatient and day-case admissions in National Health Service Wales hospitals and all Welsh residents treated in other UK countries
Welsh Longitudinal General Practice database (WLGP)	Data on all contacts with a General practice recording symptoms, diagnoses, prescriptions and procedures; includes nurse appointments and hospital referral letters
Congenital Anomaly Register and Information Service (CARIS) -from 1998	A population-based register of any foetus or infant who has a congenital anomaly whose mother is usually resident in Wales at the time of birth; congenital anomalies are defined by the European network of population-based registries for the epidemiologic surveillance of congenital anomalies
Pupil Annual School Census (PLASC) – from 2004	Pupil and school level demographic data provided by all maintained sector (local education authority schools) on primary, middle, secondary, nursery and special schools in January each year (additional demographics recorded in May during statutory assessment years (Key Stages))
National Pupil Database (NPD) – from 2004	Pupil's attainment data relating to both statutory key stage assessments and external examinations such as GCSEs; data is linked to PLASC

Supplementary table 2: Social-demographic data for Wales

	Total n (%)	
Townsend Deprivation quintile: from 2003, child's age 0 – 14 years old[a]		
1 - least deprived	-	(19.3)
2	-	(19.3)
3	-	(19.3)
4	-	(20.5)
5 - most deprived	-	(21.7)
Sex: from 2001, child's age 0 – 14 years old[b]		
Male	281767	(51.3)
Female	267437	(48.7)
Breastfeeding at birth: Welsh residents 2011[c]		
No	14469	(40.5)
Yes	18062	(50.6)
no answer	3151	(8.8)
Maternal age at childbirth: Welsh residents 2011 [c]		
<16	57	(0.2)
16-19	2409	(6.8)
19-24	8115	(22.7)
25-29 years	10268	(28.8)
30-34	9107	(25.5)
35+	5722	(16.0)
no answer	4	(0.01)
Gestational age at birth: Welsh residents 2011 [c]		
20-<32 weeks	443	(1.2)
32-<37 weeks	2094	(5.9)
37-43 weeks	32985	(92.4)
no answer	160	(0.4)
Birthweight: Welsh residents 2011 [c]		
Low: < 2500g	2403	(6.7)
Normal: ≥ 2500 - < 4000g	28991	(81.2)
High: ≥ 4000g	4249	(11.9)
no answer	39	(0.1)

[a] Deprivation and health – report for the National Public Health Service for Wales 2004; [b] Welsh data from the UK Census 2001 at https://statswales.gov.wales/; [c] Births in Wales 2001 - 2011: Data from the National Community Child Health Database 2012.