

1 **Exploring interaction effects of social determinants of health with hospital admission type on**
2 **academic performance: a data linkage study.**

3 Joanna F Dipnall*^{1,2}, PhD, Jane Lyons^{1,3,4,5}, MSc, MD, Ronan A Lyons^{1,3,5}, MD, Shanthi
4 Ameratunga^{1,6,7}, PhD, Mariana Brussoni^{8,9,10}, PhD, Frederick P Rivara¹¹, MD, Fiona E Lecky^{12,13},
5 PhD, Amy Schneeberg^{9,14}, PhD, James E Harrison¹⁵, MPH, Belinda J Gabbe^{1,3}, PhD.
6

7 **Affiliations:**

8 ¹ School of Public Health and Preventive Medicine, Monash University, Australia

9 ² Institute for Mental and Physical Health and Clinical Translation, School of Medicine, Deakin
10 University, Australia

11 ³ Population Data Science, Swansea University Medical School, Faculty of Medicine, Health & Life
12 Science, Swansea University, UK

13 ⁴ Administrative Data Research Wales

14 ⁵ National Centre for Population Health and Wellbeing Research, Swansea University, Swansea, UK

15 ⁶ School of Population Health, University of Auckland, New Zealand

16 ⁷ Population Health Gain, Te Whatu Ora (Health New Zealand) – Service Improvement &
17 Innovation, New Zealand

18 ⁸ Department of Pediatrics, School of Population and Public Health, University of British Columbia,
19 Vancouver, Canada

20 ⁹ British Columbia Children’s Hospital Research Institute, British Columbia Injury Research and
21 Prevention Unit, Vancouver, Canada

22 ¹⁰ Human Early Learning Partnership, University of British Columbia, Vancouver, Canada

23 ¹¹ Departments of Pediatrics and Epidemiology, Harborview Injury Prevention and Research Center,
24 University of Washington, Seattle, WA 98104, USA

25 ¹² Centre for Urgent and Emergency Care Research, School of Medicine and Population Health,
26 University of Sheffield, Sheffield, UK

27 ¹³ Emergency Department, Salford Royal Hospital, Salford, UK

28 ¹⁴ School of Population and Public Health, University of British Columbia, Vancouver, Canada

29 ¹⁵ Flinders Health and Medical Research Institute, Flinders University, Adelaide, South Australia,
30 Australia

31 **Address correspondence to:** Joanna Dipnall, Monash University, 553 St Kilda Road,
32 Melbourne, Victoria, 3004, Australia, [Joanna.dipnall@monash.edu], +61 3 9903 0943.

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34 **What is already known on this topic**

- 35 • Social determinants of health (SDH) effect children’s health and education outcomes.
- 36 • Childhood hospital admissions, particularly injuries, can negatively affect health
37 outcomes.
- 38 • Education is a known mediator in children’s long-term health but there is little research
39 investigating the moderating effects of SDH in the relationship between childhood
40 hospital admission and academic performance

41 **What this study adds**

- 42 • For the first time, a large Welsh population linked study demonstrates the negative effects
43 of SDH on the relationship between injury and non-injury hospital admission types with a
44 child’s educational outcome
- 45 • Our study demonstrated that the consequences of childhood hospital admissions on
46 educational outcomes is complex, with negative effects varying by SDH, particularly for
47 injury admissions

48 **How this study might affect research, practice or policy**

- 49 • Future investigation into the viability of in-hospital routine screening of families for SDH
50 and relevant post-hospital interventions to help reduce the impact of SDH on educational
51 outcomes post hospital admission is needed.

52

53 **Abstract**

54 **Objective:** To investigate the moderating effects of socio-demographic social determinants
55 of health (SDH) in the relationship between types of childhood hospitalisation (i.e. None,
56 Injury, Non-injury, Injury+Non-injury) and academic performance.

57 **Design, setting and patients:** Children residing in Wales 2009-2016 (N=369,310). Secure
58 Anonymised Information Linkage databank linked Tagged Electronic Cohort Cymru (five
59 data sources) from the Wales Electronic Cohort for Children.

60 **Main outcome measure:** Binary educational achievement (EA) measured across three key
61 educational stage (KS) time points: grade 6 (mean age 11 years, SD 0.3), 9 (mean age 14
62 years, SD 0.3), and 11 11 (mean age 16 years, SD 0.3).

63 **Results:** Of the 369,310 children, 51% were males, 25.4% of children were born in the
64 lowest two Townsend deciles. Females were more likely to meet EA than males (Adjusted
65 Risk Ratio (aRR) (95%CI): 1.047 (1.039,1.055)). EA was lower for injury admissions in
66 males and any admission type in females (Interactions: femaleXnon-injury 0.982
67 (0.975,0.989); femaleXinjury+non-injury 0.980 (0.966,0.994)). Children born into a more
68 deprived decile the were less likely to achieve EA (0.979, (0.977,0.980)), and worsened by
69 an injury admission (Interactions: townsendXinjury 0.991 (0.988,0.994);
70 TownsendXinjury+non-injury 0.997 (0.994,1.000)). Children with special educational needs
71 (sen) were less likely to meet EA (0.471, (0.459,0.484) and especially for an injury
72 admission (Interactions: senXinjury 0.932, (0.892,0.974)).

73 **Conclusion:** SDH moderated the impact of hospital admission type on educational
74 outcomes prompting future investigation into the viability of in-hospital routine screening of
75 families for SDH and relevant post-hospital interventions to help reduce the impact of SDH
76 on educational outcomes post hospitalisation.

77

78 **Introduction**

79 Social determinants of health (SDH) have an important impact on a child's health outcomes.

80 ¹ Health and development outcomes in children follow a social gradient: children with
81 higher socioeconomic status having better outcomes. ² Important skills and knowledge that
82 influence a child's wellbeing are gained directly and indirectly through education. Time
83 spent away from school (e.g. for hospital admission/hospitalisation), can result in negative
84 physical and/or psychological outcomes, and subsequent harms to educational development
85 ³ and economic opportunities throughout life. Adopting a life-course perspective, with a
86 focus on early-life experiences, is vital to reducing health disparities ^{4,5} and outcomes.
87 Policy interventions, targeted at education and early childhood, have improved population
88 health and reduced health disparities. ⁶ Education as an important determinant of health is
89 well known due to its lifelong impact. ⁷ How social determinants of health modify the
90 impact of a childhood hospital admission on academic performance is needed to inform
91 early-life interventions for children.

92 Evidence of the relationship between childhood hospitalisation and educational performance
93 is mixed. The reason for hospitalisation may be an important point of difference. Negative
94 educational achievement outcomes have been associated with several chronic diseases. ⁸⁻¹¹

95 Childhood injury is a leading contributor to the global disease burden; many millions of
96 children are hospitalised every year for non-fatal injuries, ^{12, 13} placing these children at risk
97 for adverse developmental impacts. ^{14, 15}

98 Considering the social ecological model for health and the larger community and societal
99 factors, as reflected in SDH, knowledge of the potential moderating effects of childhood
100 hospitalisation (defined here as injury- and non-injury-related hospital admissions) on
101 academic performance is needed. Such knowledge is important in order to better direct
102 interventions to those at greatest risk of poor outcomes. Therefore, we sought to elucidate

103 the relationship between childhood hospitalisation and academic performance, specifically
104 investigating the moderating effects of other SDH.

105 **Methods and Analysis**

106 This study used population linked data from the Secure Anonymised Information Linkage
107 (SAIL) databank,¹⁶ Tagged Electronic Cohort Cymru (TECC) data from the Wales
108 Electronic Cohort for Children (WECC) (Table 1) and secondary healthcare data.¹⁷ SAIL is
109 a privacy protecting Trusted Research Environment contains different data sources and
110 provides individual and household level linkage for the population of Wales, UK. SAIL uses
111 a multiple encryption system where a trusted third party, Digital Health and Care Wales,
112 matches identities (NHS number, name, date of birth, and residential address) and replaces
113 these with unique anonymized identifiers to allow data linkage.^{16,17}

114 [TABLE 1]

115 Data from 1st January 1990 to 5th February 2018 was initially extracted. However,
116 limitations in the availability of educational outcome data due to the timing of the
117 introduction of electronically captured educational records restricted the study to children
118 who had been born in Wales between 2009 and 2016 with data on at least one educational of
119 the Key Stages (KS) 2 to 4 (Supplementary Figure s1). Linked demographic, hospital and
120 educational data were made available for the pediatric Validating Injury Burden Estimates
121 Study (VIBES-Junior)¹⁸ (SAIL project 0794). A total of 369,310 children with/without a
122 hospital admission from birth and with at least one valid educational outcome measurement
123 for school grades 3 to 11 were used in this study. Hospital admissions included emergency
124 and elective hospital admissions over time, inclusive of day cases.

125 Consistent with previous educational research,^{3,19,20} the primary outcome was a binary *Core*
126 *Subject Indicator* (CSI), representing whether a child met the expected educational
127 achievement in each KS (i.e. *KS2-KS4*). *KS0/KS1* was excluded due to changes to the

128 measurements during study period rendering the outcome unusable. A hospital admission
129 type was derived from the PEDW database. A hospital admission type prior to each KS was
130 grouped into four categories (*No hospital admission, Non-injury hospital admission(s) only,*
131 *injury admission(s) only, Both injury & non-injury admissions*) to account for all
132 combinations of hospital admission types between a KS (i.e. a child having the same type or
133 two separate and different types of hospital admissions). The explanation of all variables
134 included is compiled in Table 2.²¹⁻²⁷ The child's hospital length of stay (LOS) and number
135 of hospital admissions prior to each KS, birth factor and school-based variables were used as
136 adjustment variables in the statistical models to control for potential unobserved
137 heterogeneity^{28,29} (refer Statistical Analysis section). Child age was excluded from the
138 analysis due to lack of variation in age at each KS due to the measure being routinely
139 conducted at specific school grades (i.e. grade 6, 9 and 11).

140 [TABLE 2]

141 **Statistical Analysis**

142 Population characteristics were summarized using frequencies and percentages for
143 categorical variables and mean and standard deviation (SD) for continuous variables.
144 Pearson chi-square tests and t-tests were used to compare differences across sex for
145 categorical and numeric variables respectively. Detailed tables per KS time point are
146 supplied in Supplementary Tables s1 to s3. Longitudinal Generalized Estimating Equations
147 (GEE) Poisson population average models, with schools as the main clustering variable and
148 an independent covariance structure, were used to account for the correlation of within-
149 subject data (i.e. children within schools with repeated KS measures) and generated risk
150 ratios with robust standard errors for effect sizes at the 95% confidence interval. The
151 modified Poisson model was used as these models are preferable to logistic models, provide
152 unbiased estimates of risk ratios,³⁰⁻³³ and are a suitable alternative to log binomial

153 regression for analysis of clustered data using GEE. ³³
154 Based on prior research ²⁰ an initial adjusted multivariable GEE model, excluding SDH
155 interactions confirmed the negative relationship of hospital admission on educational
156 attainment. The main multivariable GEE model investigated the moderating effects of SDH
157 on hospital admission type using interaction terms. Interactions between the time invariant
158 SDH variables (i.e. sex, maternal age at birth and SES at birth) and time varying SDH
159 variables (i.e. change in SES, disadvantage and potential learning disabilities) were included
160 in the main model to understand the moderating effects of both static and dynamic elements
161 of a child's background. The GEE analyses and exponentiated linear predictions were
162 performed using Stata version 18.0 (Stata Corp, College Station, TX). The precision of the
163 estimates was examined using 95% confidence intervals for the GEE models. An $\alpha < 0.05$
164 was considered significant. Due to the complexity of the interactions in the final model, the
165 exponentiated linear predictions from the adjusted GEE model were graphed using R
166 software Version 4.2.3 in RStudio V2022.07.1 using the ggplot2 package ³⁴ for the
167 interpretation of the SDH moderating effects.

168 **Ethics Approval**

169 The project was approved by the Monash University Human Research Ethics Committee
170 (project number 12311) and by the SAIL data team (refer Data Statement). ³⁵⁻³⁹

171 **Results**

172 *Population Characteristics*

173 Of the 369,310 children, 51% were males; females were less likely to be admitted to hospital
174 (males 72.6%; females 70.9%) (Table 3). Twenty-five percent of children were born into the
175 lowest two Townsend deciles, 32.1% were born to a mother under 25 years of age and the
176 average gestational age was classed as full term (39.32 weeks, SD 2.1). The proportion of
177 children meeting the academic achievement level was 83.6%, 74.0% and 51.1% at KS2,

178 KS3 and KS4, respectively (Supplementary Tables s1 to s3). Further details per KS time
179 point are provided in Supplementary Tables s1 to s3.

180 [TABLE 3]

181 *Effects of SDH: Sex*

182 The effect of a child's hospital admission type on educational attainment differed according
183 to sex (Table 4). Females were more likely to meet the required academic performance than
184 males and the pattern of the difference between males and females varied according to
185 hospital admission type (Figure 1A). For males, the likelihood of meeting the required
186 academic achievement was similar if they had no admission or a non-injury admission, but
187 lower if they had an injury hospital admissions or injury + non-injury hospital admissions.
188 However, for females, the likelihood of meeting the required academic achievement was
189 lower if they had any type of hospital admission compared to no hospital admission.

190 *Effects of SDH: Maternal age at birth*

191 Overall, the negative impact of a hospital admission (i.e. of any type) on meeting the
192 required academic performance was most marked for children born to mothers aged 18 to 29
193 years; particularly for injury-related admissions (Table 4). The patterns of likelihood of
194 meeting the required academic across a mother's age group differed according to hospital
195 admission type (Figure 1B).

196 *Effects of SDH: SES*

197 Any type of hospital admission prior to a KS moderated the relationship between SES at
198 birth and meeting the educational achievement level (Table 4). The more deprived the area
199 that a child was born into (based on area-level Townsend decile), the less likely the child
200 would achieve the required academic performance. This deficit was most evident for
201 children with any injury-related hospital admission, for whom the downward slope from *1-*
202 *Least to 10-Most* deprived was the steepest (Figure 1C). Overall, children with no hospital

203 admission who moved to a less deprived area were more likely to meet the educational
204 achievement compared to children who had been admitted to hospital (Table 4, Figure 1D).
205 This differed for children who either moved to a more deprived area or had no change,
206 where there was less of an impact of a non-injury admission.
207 Overall, children eligible for free school meals were less likely to meet the educational
208 achievement, and this negative impact was accentuated if a child had any injury-related
209 hospital admission (Table 4, Figure 1E). However, the patterns of likelihood to meet the
210 educational achievement differed, with the impact of a non-injury admission lower than no
211 admission for children not eligible for school meals.

212 *Effects of SDH: Health Inequalities*

213 An injury hospital admission prior to a KS moderated the relationship between requiring
214 special educational needs (SEN) and meeting the educational achievement level, with
215 different patterns of likelihood per admission types (Table 4, Figure 1F). Overall, children
216 with special educational needs were less likely than others to meet the expected educational
217 achievement level and especially for children who had injury-related admissions.

218 [TABLE 4]

219 [FIGURE 1]

220 **Discussion**

221 This study found that hospital admission during the school age years negatively impacted on
222 a child's educational achievement, particularly if there was a hospitalisation due to an injury.
223 SDH moderated this relationship to varying degrees. A child's sex, SES status (both at birth
224 and during their school-life), and learning disability were found have to the greatest negative
225 moderating effect. An injury hospitalisation in childhood impacts on a child's education in a
226 variety of ways, including time missed from school, persisting physical and psychological
227 effects of the injury, ongoing care and complications of care. These impacts could be

228 compounded by the moderating effects of SDH.

229 Overall, females have been found to perform better than males at school.⁴⁰ The disparity in
230 educational outcomes by type of hospital admission between Welsh males and females
231 highlights the importance of this SDH. The higher rates of disciplinary problems, lower
232 achievement scores, and fewer high school completions for males compared to females from
233 comparable disadvantaged backgrounds⁴¹ may explain much of this difference. However,
234 the impact of an injury-related hospital admission warrants further consideration in injury
235 prevention strategies: differences across sex in injuries commence in infancy.⁴² Males tend
236 to sustain high-energy events⁴³ and have higher risks for childhood unintentional injuries.⁴⁴

237 This study reiterated the importance of area-based SES on a child's educational
238 achievement, especially for children who experienced an injury related hospital admission.
239 Welsh children born in a more deprived area, or who moved to a more deprived area during
240 their school years, and were admitted to hospital with an injury during their school years had
241 a lower likelihood of reaching the required academic achievement. The known disparities
242 across SES in the availability of access to services, rehabilitation outcomes and service
243 provision for pediatric patients relying on public insurance⁴⁵ negatively impacts a child's
244 recovery from injury and non-injury related hospital admissions. Children from low SES
245 areas have a lower health related quality of life post-injury over time compared to children
246 from higher SES⁴⁶ and are less likely to have access to healthcare⁴⁷ and a regular doctor,⁴⁸
247 which could impede their return to school. The 2011 Welsh education report tackling
248 problems of disadvantage focused on planning, systematic approaches, appropriate support
249 and partnerships and adequate impact assessment⁴⁹ but appropriate healthcare support
250 services in more deprived Welsh areas to support families and children post injury related
251 hospital admission is needed. Our study concurs with a recent systematic review of health
252 care disparities in paediatric rehabilitation after hospitalisation with traumatic injury which

253 identified significant effects of health care disparities on the rehabilitation process in
254 paediatric traumatic injury.⁴⁵

255 The observed interactions between a child having special educational needs and
256 experiencing certain types of hospitalisation is complicated by the diversity of reasons for
257 the former. Learning difficulties compromise students' academic learning and motivation,
258 which can hinder educational development.⁵⁰ This study highlights urgent need for
259 governments to support families and schools with students with special educational needs
260 after hospital admission. Funding and support for schools to provide adequate facilities and
261 knowledgeable teaching staff to tailor to the student's special educational needs, establish
262 clear measurable goals, consider alternative strategies for use by teaching assistants, and
263 ensure adjustments are monitored⁵¹ is needed following injury hospitalisations.

264 Further research is warranted to investigate the effectiveness of targeted interventions to
265 reduce the negative effects of a child's hospital admission on educational achievement.

266 Interventions involving closer collaboration between hospital staff, schools and
267 parents/carers to understand and address a child's individual needs during and following
268 hospital admission may be worth considering. This could include tailored approaches
269 engaging children, families and school staff in catch-up learning programs.⁵²

270 *Strengths and Limitations*

271 This research study has notable strengths. The study included a large sample of children
272 from Wales and a well-established measure of educational attainment. The ability to link
273 children to type of hospital admission over a considerable period of time enabled this study
274 to include both injury and non-injury hospital admissions. However, this study has some
275 limitations. The hospital discharge data records the reason for admission and the co-
276 morbidities impacting on treatment/management during the admission, but not all co-
277 morbidities. This study did not include the severity of the injury or illness as data related to

278 severity of the admitting condition was not available. Future research into links between
279 specific reasons for a child’s hospital admission and education achievement would be
280 beneficial. The educational data excluded any home-schooled children. While it is
281 mandatory for children in Wales to stay in school until 16 years of age, data on the small
282 proportion who dropped out of school were not available. This study was undertaken in a
283 high-income country and the patterns may differ in low to middle income countries.
284 Learnings from this study may also be used in future research to investigate the potential
285 mediating effects of a child’s hospital length of stay and/or number of hospital admissions in
286 the relationship between academic performance and the type of hospital.

287 **Conclusion**

288 This study quantifies the moderating effects of SDH on the relationship between hospital
289 admission type with educational outcome. The educational outcome for a child admitted to
290 hospital with an injury is negatively impacted by a child’s sex, SES, maternal age at birth,
291 and health inequities. These findings suggest an urgent priority for further research into the
292 viability of routinely screening families for SDH prior to a child’s hospital discharge in
293 order to provide referrals to appropriate services to support the child’s schooling years to
294 improve their educational outcomes.

Data Statement

This study makes use of anonymized data held in the Secure Anonymised Information Linkage (SAIL) Databank. We would like to acknowledge all the data providers who make anonymised data available for research. Data are available from the SAIL Databank at HDRUK Swansea University <https://saildatabank.com/> or contact SAILDatabank@swansea.ac.uk. For further information on access including training required see website: <https://saildatabank.com/data/apply-to-work-with-the-data/>. We confirm that the authors did not have any special access privileges.

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Conflict of Interest Disclosures (includes financial disclosures)

There are no competing interests to declare.

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Abbreviations:

ACOG	American College of Obstetricians and Gynecologists
ADBE	Annual District Birth Extract
ADDE	Annual District Death Extract
CI	Confidence Interval
CSI	Core Subject Indicator
EDUW	Educational Wales database
KS	Key stage
ICD-10	International Classification of Diseases 10th Revision
ICH	International Council for Harmonisation
NCCHD	National Community Health Database
NHMRC	National Health and Medical Research Council
PEDW	Patient Episode Database for Wales
RR	Risk Ratio
SAIL	Secure Anonymised Information Linkage

SDH	Social Determinants of Health
SES	Socioeconomic Status
SD	Standard deviation
SMFM	Society for Maternal–Fetal Medicine
TECC	Tagged Electronic Cohort Cymru
VIBES- Junior	Validating Injury Burden Estimates Study
WDSD	Welsh Demographic Service Dataset
WECC	Wales Electronic Cohort for Children
WHO	World Health Organization

Contributors Statement Page

Dr Joanna Dipnall contributed to the study design, designed and performed the analysis and drafted the initial manuscript and critically reviewed and revised the manuscript and is responsible for the overall content as guarantor. Jane Lyons critically reviewed and revised the manuscript. Professor Lyons conceptualized and designed the study critically reviewed and revised the manuscript. Professor Ameratunga conceptualized and designed the study critically reviewed and revised the manuscript. Professor Mariana Brussoni conceptualized and designed the study critically reviewed and revised the manuscript. Professor Rivara conceptualized and designed the study critically reviewed and revised the manuscript. Professor Lecky conceptualized and designed the study critically reviewed and revised the manuscript. Dr Schneeberg critically reviewed and revised the manuscript. Professor Harrison conceptualized and designed the study critically reviewed and revised the manuscript. Professor Gabbe conceptualized and designed the study critically reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

TABLES:

Table 1: Linked Data Used in this Study

Data Sets	Data used in study
Welsh Demographic Service Dataset (WDSD).	Demographic data
Annual District Birth Extract (ADBE)	Birth register data
Annual District Death Extract (ADDE)	Death register data
Patient Episode Database for Wales (PEDW)	Hospital inpatient data
Education Wales (EDUW) database	Educational data

Table 2: Variables Used in Study Analysis

Variable	Description
Outcome: Educational Achievement Measure	
Binary <i>Core Subject Indicator</i> (CSI) to indicate a child met the expected educational achievement: <i>1=Met achievement level</i> <i>0=Not met achievement level</i>	Primary outcome was a binary <i>Core Subject Indicator</i> (CSI) measure which represented if a child met the expected educational achievement. The CSI was derived from teacher assessments in the three core subjects of language, mathematics and science and was conducted for children across each KS from primary to secondary school.
Time Points: Key Stages (KS)	
Educational KS: <i>KS2 (grades 3-6, measured at grade 6)</i> <i>KS3 (grades 7-9, measured at grade 9)</i> <i>KS4 (grades 10-11, measured at grade 11).</i>	Three Educational Key Stage (KS) were used as the time points in this longitudinal study.
Hospital Variables	
Hospital admission type between KS: <i>None = No hospital admission</i> <i>Non-injury = Non-injury hospital admission(s) only</i> <i>Injury = injury admission(s) only</i> <i>Injury + Non-injury = Both injury & non-injury admissions</i>	A child's hospital admission status was derived from the PEDW database which categorized children based on their interaction with inpatient service. Hospital admission status captured all hospital admissions. A child's hospital admissions status prior to a KS was grouped into four categories. The definition of an <i>injury</i> admission was taken from the principal diagnosis using ICD-10 injury definitions and excluded cases with complications/sequelae (i.e. ICD-10 T80-T98) as in this case an acute injury was not the primary reason for the child's hospital admission. A <i>non-injury</i> admission was a hospital admission not classified as an injury.
Hospital length of Stay (LOS): <i>Numeric integer (days)</i>	Length of hospital stay per child prior to each KS was calculated from subtracting the date of discharge from date of admission and summated for children with more than one hospital admission prior to each KS.
Number of hospital admissions <i>Numeric integer</i>	Number of hospital admissions prior to each KS were summated.
Social Determinants of Health (SDH)	
Sex: <i>Male</i> <i>Female</i>	The child's sex at birth was included as sex is an important component of social determinants of health, evident in the conceptual origins described by Marmot ²¹ and incorporated in the WHO's Social Determinants of Health program of work. ²²
Maternal age at birth: <i><18 years</i> <i>18-24 years</i> <i>25-29 years</i> <i>30-34 years</i> <i>35+ years</i> <i>Unknown</i>	Maternal age at birth was grouped into six categories and informed by prior research. ³
Townsend decile:	The child's area-based socioeconomic status (SES) was

Numeric integer

measured by the Townsend decile at birth score. This measure is a United Kingdom (UK) measure representing socioeconomic status (SES)²³ where the higher the score the more a deprived area. The Townsend decile was included as a continuous covariate in the models to formulate a more parsimonious model after finding the categorical covariate represented a general linear trend.

Change in Townsend:

No change in Townsend

Changed to less deprived area

Changed to more deprived area

The change in Townsend (SES) between each KS time point was calculated and grouped into three categories. Missing Townsend decile scores between KS replaced with carry forward values from the previous KS period.²⁰

Eligible for free school meal:

No

Yes

Any special educational needs:

No

Yes

The student's eligibility for free school meal at each KS time point was included as indicative measures of disadvantage.²⁴

The mention of any special educational needs at each KS time point was included as indicative measure of potential learning disabilities/health inequities.²⁵ In Wales children with more complex needs might have a statement of special educational needs, which is a legal document which sets out the child's special educational needs and all the additional help that will be given to meet those needs.

Birth Factors

Caesarian section:

No

Yes

Whether the child was born via caesarian section was included as a potential confounding variable consistent with research investigating injury-related hospital admissions.²⁰

Gestational age:

Extreme preterm (<28 weeks)

Very preterm (28-32 weeks),

Moderate or Late preterm (33-36 weeks)

Early term (37-38 weeks)

Full term (39-40 weeks),

Later term (41-42 weeks)

Post term (43+ weeks)

Gestational age groups were informed by the WHO preterm definition, The American College of Obstetricians and Gynecologists (ACOG) and the Society for Maternal-Fetal Medicine (SMFM) definitions of term pregnancy.^{26, 27}

School Factors

Calendar school year:

Numeric integer

Calendar school year was included to control for potential institutional and governmental changes over time.

School pupil size;

<=100 pupils

>100-150 pupils

>150-200 pupils

>200-300 pupils

>300 pupils)

Consistent with previous educational research school pupil size was grouped into five categories.^{3, 20}

Table 3 Overall population characteristics†

	Total N=369310	Male N=188791	Female N=180519	p-value*
Sex				<0.001
Male	188791 (51.1%)	188791 (100.0%)		
Female	180519 (48.9%)		180519 (100.0%)	
Townsend decile at birth				0.050
1 - Least deprived	29450 (8.0%)	15016 (8.0%)	14434 (8.0%)	
2	29058 (7.9%)	14834 (7.9%)	14224 (7.9%)	
3	30959 (8.4%)	16052 (8.5%)	14907 (8.3%)	
4	31713 (8.6%)	16265 (8.6%)	15448 (8.6%)	
5	35260 (9.5%)	18042 (9.6%)	17218 (9.5%)	
6	36128 (9.8%)	18468 (9.8%)	17660 (9.8%)	
7	39781 (10.8%)	20520 (10.9%)	19261 (10.7%)	
8	37971 (10.3%)	19306 (10.2%)	18665 (10.3%)	
9	42207 (11.4%)	21450 (11.4%)	20757 (11.5%)	
10 - Most deprived	51872 (14.0%)	26300 (13.9%)	25572 (14.2%)	
Missing	4911 (1.3%)	2538 (1.3%)	2373 (1.3%)	
Maternal age (years) (mean, SD)	27.49 (5.81)	27.50 (5.81)	27.47 (5.81)	0.11
Maternal age group				0.28
<18 years	11580 (3.1%)	5917 (3.1%)	5663 (3.1%)	
18-24 years	107116 (29.0%)	54624 (28.9%)	52492 (29.1%)	
25-29 years	111892 (30.3%)	57028 (30.2%)	54864 (30.4%)	
30-34 years	93423 (25.3%)	48035 (25.4%)	45388 (25.1%)	
35+ years	44559 (12.1%)	22801 (12.1%)	21758 (12.1%)	
Missing	740 (0.2%)	386 (0.2%)	354 (0.2%)	
Gestational age (weeks) (mean, SD)	39.32 (2.10)	39.28 (2.13)	39.36 (2.06)	<0.001
Gestational age group				<0.001
Extreme preterm (<28 weeks)	842 (0.2%)	435 (0.2%)	407 (0.2%)	
Very preterm (28-32 weeks)	4605 (1.2%)	2547 (1.3%)	2058 (1.1%)	
Moderate or late preterm (33-36 weeks)	20773 (5.6%)	11177 (5.9%)	9596 (5.3%)	
Early term (37-38 weeks)	65939 (17.9%)	34431 (18.2%)	31508 (17.5%)	
Full term (39-40 weeks)	174770 (47.3%)	88401 (46.8%)	86369 (47.8%)	
Later term (41-42 weeks)	92294 (25.0%)	46705 (24.7%)	45589 (25.3%)	
Post term (43+ weeks)	4470 (1.2%)	2200 (1.2%)	2270 (1.3%)	
Missing	5617 (1.5%)	2895 (1.5%)	2722 (1.5%)	
Child born by cesarean section				<0.001
No	318056 (86.1%)	161457 (85.5%)	156599 (86.7%)	
Yes	51254 (13.9%)	27334 (14.5%)	23920 (13.3%)	
Hospital admission status				<0.001
Had hospital admission	264884 (71.7%)	136969 (72.6%)	127915 (70.9%)	
No hospital admission	104426 (28.3%)	51822 (27.4%)	52604 (29.1%)	
Educational achievement scores^ across KS				0.32
One score	70096 (19.0%)	35791 (19.0%)	34305 (19.0%)	
Two scores	195350 (52.9%)	100081 (53.0%)	95269 (52.8%)	
Three scores	103864 (28.1%)	52919 (28.0%)	50945 (28.2%)	

^Note: Educational achievement score = Binary CSI measure of meeting the expected educational achievement. * Pearson chi-square test and t-test used to compare across categorical and numeric variables respectively. † Refer to Supplementary Tables s1 to s3 for detailed longitudinal metrics (e.g. hospital admission type).

Table 4: Multivariable Model Results for Met the Required Educational Achievement Level.

	aRR	Non-Interaction Model 95% CI	p-value	aRR	Interaction Model 95% CI	p-value
Hospital admission type						
No hospital admission	<i>Ref</i>			<i>Ref</i>		
Non-injury only	0.979	(0.974,0.983)	<0.001	0.955	(0.945,0.966)	<0.001
Injury only	0.941	(0.932,0.950)	<0.001	0.989	(0.966,1.013)	0.38
Injury + Non-injury	0.936	(0.928,0.945)	<0.001	0.955	(0.935,0.974)	<0.001
Sex						
Male	<i>Ref</i>			<i>Ref</i>		
Female	1.037	(1.031,1.044)	<0.001	1.047	(1.039,1.055)	<0.001
Child born by caesarean section						
No	<i>Ref</i>			<i>Ref</i>		
Yes	0.999	(0.994,1.004)	0.67	0.999	(0.995,1.004)	0.75
Townsend decile at birth						
	0.980	(0.978,0.981)	<0.001	0.979	(0.977,0.980)	<0.001
Maternal age group						
<18 years	0.901	(0.886,0.916)	<0.001	0.884	(0.862,0.906)	<0.001
18-24 years	0.938	(0.932,0.945)	<0.001	0.921	(0.912,0.930)	<0.001
25-29 years	<i>Ref</i>			<i>Ref</i>		
30-34 years	1.017	(1.012,1.022)	<0.001	1.018	(1.011,1.026)	<0.001
35+ years	1.017	(1.010,1.024)	<0.001	1.009	(0.999,1.019)	0.07
Gestational age group						
Extreme preterm (<28 weeks)	0.938	(0.884,0.995)	0.033	0.936	(0.882,0.993)	0.029
Very preterm (28-32 weeks)	0.958	(0.938,0.978)	<0.001	0.958	(0.938,0.978)	<0.001
Moderate or late preterm (33-36 weeks)	0.994	(0.985,1.003)	0.18	0.994	(0.985,1.003)	0.18
Early term (37-38 weeks)	0.999	(0.994,1.004)	0.72	0.999	(0.994,1.004)	0.72
Full term (39-40 weeks)	<i>Ref</i>			<i>Ref</i>		
Later term (41-42 weeks)	1.010	(1.005,1.015)	<0.001	1.010	(1.005,1.015)	<0.001
Post term (43+ weeks)	0.983	(0.956,1.009)	0.20	0.982	(0.956,1.009)	0.19
Change in Townsend decile						
No change in Townsend	<i>Ref</i>			<i>Ref</i>		
Changed to less deprived area	1.015	(1.008,1.022)	<0.001	1.030	(1.020,1.039)	<0.001
Changed to more deprived area	0.955	(0.949,0.961)	<0.001	0.955	(0.946,0.964)	<0.001
Eligible for free school meal						
No	<i>Ref</i>			<i>Ref</i>		
Yes	0.805	(0.794,0.815)	<0.001	0.792	(0.779,0.805)	<0.001
Any special educational needs						
No	<i>Ref</i>			<i>Ref</i>		
Yes	0.485	(0.475,0.496)	<0.001	0.471	(0.459,0.484)	<0.001
School pupil size						
<=100 pupils	<i>Ref</i>			<i>Ref</i>		
>100-150 pupils	1.060	(1.032,1.089)	<0.001	1.061	(1.033,1.089)	<0.001
>150-200 pupils	1.089	(1.062,1.117)	<0.001	1.089	(1.062,1.117)	<0.001
>200-300 pupils	1.071	(1.045,1.096)	<0.001	1.071	(1.046,1.097)	<0.001
>300 pupils	1.083	(1.054,1.113)	<0.001	1.084	(1.055,1.114)	<0.001
Hospital length of stay (days)						
	1.000	(1.000,1.000)	0.028	1.000	(1.000,1.000)	0.033
Maximum number of hospital admissions						
	0.996	(0.995,0.998)	<0.001	0.996	(0.995,0.997)	<0.001
Key Stage (KS)						
2	<i>Ref</i>			<i>Ref</i>		
3	0.868	(0.856,0.881)	<0.001	0.868	(0.856,0.880)	<0.001
4	0.592	(0.576,0.609)	<0.001	0.592	(0.576,0.609)	<0.001
Year	1.037	(1.034,1.039)	<0.001	1.037	(1.034,1.039)	<0.001
Interactions						
Sex						
Male				<i>Ref</i>		
Female x No hospital admission				<i>Ref</i>		
Female x Non-injury only				0.982	(0.975,0.989)	<0.001
Female x Injury only				1.019	(1.000,1.038)	0.05
Female x Injury + Non-injury				0.980	(0.966,0.994)	0.005
Maternal age group						
<18 years x No hospital admission				<i>Ref</i>		
<18 years x Non-injury only				1.030	(0.998,1.063)	0.06
<18 years x Injury only				1.003	(0.933,1.078)	0.93

<18 years x Injury + Non-injury	1.048	(0.995,1.105)	0.08
18-24 years x No hospital admission	<i>Ref</i>		
18-24 years x Non-injury only	1.031	(1.020,1.042)	<0.001
18-24 years x Injury only	1.011	(0.984,1.038)	0.44
18-24 years x Injury + Non-injury	1.039	(1.018,1.061)	<0.001
25-29 years (Ref age group)	<i>Ref</i>		
30-34 years x No hospital admission	<i>Ref</i>		
30-34 years x Non-injury only	0.994	(0.985,1.002)	0.15
30-34 years x Injury only	1.013	(0.992,1.035)	0.22
30-34 years x Injury + Non-injury	1.012	(0.994,1.031)	0.18
35+ years x No hospital admission	<i>Ref</i>		
35+ years x Non-injury only	1.007	(0.997,1.018)	0.19
35+ years x Injury only	1.053	(1.025,1.082)	<0.001
35+ years x Injury + Non-injury	1.031	(1.008,1.055)	0.009
Townsend decile at birth			
No hospital admission	<i>Ref</i>		
Non-injury only	1.004	(1.002,1.005)	<0.001
Injury only	0.991	(0.988,0.994)	<0.001
Injury + Non-injury	0.997	(0.994,1.000)	0.049
Change in Townsend decile			
No change in Townsend	<i>Ref</i>		
Changed to less deprived area x No hospital admission	<i>Ref</i>		
Changed to less deprived area x Non-injury only	0.975	(0.966,0.985)	<0.001
Changed to less deprived area x Injury only	0.981	(0.957,1.005)	0.11
Changed to less deprived area x Injury + Non-injury	0.977	(0.957,0.997)	0.023
Changed to more deprived area x No hospital admission	<i>Ref</i>		
Changed to more deprived area x Non-injury only	1.002	(0.990,1.014)	0.74
Changed to more deprived area x Injury only	0.985	(0.954,1.016)	0.34
Changed to more deprived area x Injury + Non-injury	0.998	(0.974,1.023)	0.89
Eligible for free school meal			
No	<i>Ref</i>		
Yes x No hospital admission	<i>Ref</i>		
Yes x Non-injury only	1.032	(1.017,1.047)	<0.001
Yes x Injury only	0.976	(0.942,1.010)	0.16
Yes x Injury + Non-injury	1.015	(0.989,1.041)	0.27
Any special educational needs			
No	<i>Ref</i>		
Yes x No hospital admission	<i>Ref</i>		
Yes x Non-injury only	1.065	(1.044,1.088)	<0.001
Yes x Injury only	0.932	(0.892,0.974)	0.002
Yes x Injury + Non-injury	0.987	(0.957,1.018)	0.39

Note: aRR = adjusted Risk Ratio. CI = Confidence Interval. Bold indicates significant p<0.05. Outcome: Binary CSI for meeting the expected educational achievement: 1=Met achievement level; 0=Not met achievement level.

FIGURES:

Figure 1: Predicted Probability of Meeting the Required Educational Achievement Level.
Note: Exponentiated linear predictions generated from the adjusted GEE model with interactions (Table 4).