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

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What is already known on this topic

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

What this study adds

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

How this study might affect research, practice or policy

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

Abstract

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

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

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

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

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

Introduction

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

Evidence of the relationship between childhood hospitalisation and educational performance is mixed. The reason for hospitalisation may be an important point of difference. Negative educational achievement outcomes have been associated with several chronic diseases. [8-11] Childhood injury is a leading contributor to the global disease burden; many millions of children are hospitalised every year for non-fatal injuries, [12, 13] placing these children at risk for adverse developmental impacts. [14, 15]

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

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

Methods and Analysis

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

[TABLE 1]

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

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

measurements during study period rendering the outcome unusable. A hospital admission type was derived from the PEDW database. A hospital admission type prior to each KS was grouped into four categories (*No hospital admission, Non-injury hospital admission(s) only, injury admission(s) only, Both injury & non-injury admissions*) to account for all combinations of hospital admission types between a KS (i.e. a child having the same type or two separate and different types of hospital admissions). The explanation of all variables included is compiled in Table 2. [21-27]. The child's hospital length of stay (LOS) and number of hospital admissions prior to each KS, birth factor and school-based variables were used as adjustment variables in the statistical models to control for potential unobserved heterogeneity [28,29] (refer Statistical Analysis section). Child age was excluded from the analysis due to lack of variation in age at each KS due to the measure being routinely conducted at specific school grades (i.e. grade 6, 9 and 11).

[TABLE 2]

Statistical Analysis

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

regression for analysis of clustered data using GEE. [33]

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

Ethics Approval

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

Results

Population Characteristics

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

admission who moved to a less deprived area were more likely to meet the educational achievement compared to children who had been admitted to hospital (Table 4, Figure 1D). This differed for children who either moved to a more deprived area or had no change, where there was less of an impact of a non-injury admission.

Overall, children eligible for free school meals were less likely to meet the educational achievement, and this negative impact was accentuated if a child had any injury-related hospital admission (Table 4, Figure 1E). However, the patterns of likelihood to meet the educational achievement differed, with the impact of a non-injury admission lower than no admission for children not eligible for school meals.

Effects of SDH: Health Inequalities

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

[TABLE 4]

[FIGURE 1]

Discussion

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

compounded by the moderating effects of SDH.

Overall, females have been found to perform better than males at school. [40] The disparity in educational outcomes by type of hospital admission between Welsh males and females highlights the importance of this SDH. The higher rates of disciplinary problems, lower achievement scores, and fewer high school completions for males compared to females from comparable disadvantaged backgrounds [41] may explain much of this difference. However, the impact of an injury-related hospital admission warrants further consideration in injury prevention strategies: differences across sex in injuries commence in infancy. [42] Males tend to sustain high-energy events [43] and have higher risks for childhood unintentional injuries. [44] This study reiterated the importance of area-based SES on a child's educational achievement, especially for children who experienced an injury related hospital admission. Welsh children born in a more deprived area, or who moved to a more deprived area during their school years, and were admitted to hospital with an injury during their school years had a lower likelihood of reaching the required academic achievement. The known disparities across SES in the availability of access to services, rehabilitation outcomes and service provision for pediatric patients relying on public insurance [45] negatively impacts a child's recovery from injury and non-injury related hospital admissions. Children from low SES areas have a lower health related quality of life post-injury over time compared to children from higher SES [46] and are less likely to have access to healthcare [47] and a regular doctor, [48] which could impede their return to school. The 2011 Welsh education report tackling problems of disadvantage focused on planning, systematic approaches, appropriate support and partnerships and adequate impact assessment [49] but appropriate healthcare support services in more deprived Welsh areas to support families and children post injury related hospital admission is needed. Our study concurs with a recent systematic review of health care disparities in paediatric rehabilitation after hospitalisation with traumatic injury which

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

The observed interactions between a child having special educational needs and experiencing certain types of hospitalisation is complicated by the diversity of reasons for the former. Learning difficulties compromise students' academic learning and motivation, which can hinder educational development. [50] This study highlights urgent need for governments to support families and schools with students with special educational needs after hospital admission. Funding and support for schools to provide adequate facilities and knowledgeable teaching staff to tailor to the student's special educational needs, establish clear measurable goals, consider alternative strategies for use by teaching assistants, and ensure adjustments are monitored [51] is needed following injury hospitalisations.

Further research is warranted to investigate the effectiveness of targeted interventions to reduce the negative effects of a child's hospital admission on educational achievement. Interventions involving closer collaboration between hospital staff, schools and parents/carers to understand and address a child's individual needs during and following hospital admission may be worth considering. This could include tailored approaches engaging children, families and school staff in catch-up learning programs. [52]

Strengths and Limitations

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

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

Conclusion

This study quantifies the moderating effects of SDH on the relationship between hospital admission type with educational outcome. The educational outcome for a child admitted to hospital with an injury is negatively impacted by a child's sex, SES, maternal age at birth, and health inequities. These findings suggest an urgent priority for further research into the viability of routinely screening families for SDH prior to a child's hospital discharge in order to provide referrals to appropriate services to support the child's schooling years to 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 *Core Subject Indicator* (CSI) to indicate a child met the expected educational achievement: *1=Met achievement level* *0=Not met achievement level*	Primary outcome was a binary *Core Subject Indicator* (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: *KS2 (grades 3-6, measured at grade 6)* *KS3 (grades 7-9, measured at grade 9)* *KS4 (grades 10-11, measured at grade 11).*	Three Educational Key Stage (KS) were used as the time points in this longitudinal study.
Hospital Variables	
Hospital admission type between KS: *None = No hospital admission* *Non-injury = Non-injury hospital admission(s) only* *Injury = injury admission(s) only* *Injury + Non-injury = Both injury & non-injury admissions*	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 *injury* 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 *non-injury* admission was a hospital admission not classified as an injury.
Hospital length of Stay (LOS): *Numeric integer (days)*	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 *Numeric integer*	Number of hospital admissions prior to each KS were summated.
Social Determinants of Health (SDH)	
Sex: *Male* *Female*	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: *<18 years* *18-24 years* *25-29 years* *30-34 years* *35+ years* *Unknown*	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*	The student's eligibility for free school meal at each KS time point was included as indicative measures of disadvantage. [24]
Any special educational needs: *No* *Yes*	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.

	Non-Interaction Model			Interaction Model		
	aRR	95% CI	p-value	aRR	95% CI	p-value
Hospital admission type						
No hospital admission	*Ref*			*Ref*		
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	*Ref*			*Ref*		
Female	1.037	(1.031,1.044)	**<0.001**	1.047	(1.039,1.055)	**<0.001**
Child born by caesarean section						
No	*Ref*			*Ref*		
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	*Ref*			*Ref*		
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)	*Ref*			*Ref*		
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	*Ref*			*Ref*		
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	*Ref*			*Ref*		
Yes	0.805	(0.794,0.815)	**<0.001**	0.792	(0.779,0.805)	**<0.001**
Any special educational needs						
No	*Ref*			*Ref*		
Yes	0.485	(0.475,0.496)	**<0.001**	0.471	(0.459,0.484)	**<0.001**
School pupil size						
<=100 pupils	*Ref*			*Ref*		
>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	*Ref*			*Ref*		
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				*Ref*		
Female x No hospital admission				*Ref*		
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				*Ref*		
<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	*Ref*		
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)	*Ref*		
30-34 years x No hospital admission	*Ref*		
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	*Ref*		
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	*Ref*		
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	*Ref*		
Changed to less deprived area x No hospital admission	*Ref*		
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 admissio	*Ref*		
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	*Ref*		
Yes x No hospital admission	*Ref*		
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	*Ref*		
Yes x No hospital admission	*Ref*		
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).