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ORIGINAL ARTICLE

Dental caries and school readiness in 5-year-olds: A birth cohort data linkage study

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Abstract

Objective: To describe the association between dental caries and school readiness in 5-year-old children taking part in the Born in Bradford (BiB) birth cohort, UK.

Methods: The Early Years Foundation Stage Profile (EYFSP) assesses the school readiness of young children and is strongly predictive of future academic attainment. Children are recorded as 'emerging' (below expected), 'expected', or 'exceeding' in five key learning areas. The Oral Health Survey of 5-year-olds (OHS5) is undertaken biennially in England, assessing caries experience at a dentine threshold ($d_3$mft). EYFSP and OHS5 were available for a proportion of children participating in BiB. Odds ratios and confidence intervals for caries experience were established, and odds ratios adjusted for significant sociodemographic variables.

Results: EYFSP and OHS5 data were available for 2.5% ($n = 346$) BiB participants. Nearly half (45.2%) had caries. A measure of socio-economic status, receiving free school meals, was the only demographic variable strongly related to caries experience (OR: 2.8, 95% CI: 1.6–4.9). After adjustment, children 'emerging' in EYFSP learning areas had 1.6- to 2.2-fold (95% CI: 1.0–3.8) higher odds of experiencing caries. Children 'exceeding' EYFSP learning areas had 2.3- to 4-fold (95% CI: 0.1–0.9) lower odds of caries experience.

Conclusion: This is the first study to explore the association between caries experience and school readiness using a holistic assessment tool. The association was found across different learning areas and was comparable to and independent of socio-economic status. The findings indicate oral health-related absenteeism is not a causative factor. EYFSP shows potential to enhance the targeting of preventive interventions at a child, class or school level.

KEYWORDS
Early childhood caries, Oral health, Pediatric dentistry, Disparities

1 | BACKGROUND

The global burden of dental caries (tooth decay) in childhood is substantial, despite being a preventable disease. Caries has a direct impact on a child's quality of life, with untreated disease causing toothache, sleepless nights and altered eating habits.[1-3] It is estimated that over 600 million children worldwide experience caries in one or more primary teeth, with significant consequences for the child, family and wider community.[4] In England, treatment of caries is the most common reason for a child to have a general anaesthetic,[5] with £60 million spent annually in public hospitals,[6] despite a substantial number of dental procedures remaining unreported by national hospital statistics.[7] Establishing optimal oral health behaviours in early childhood, particularly in at-risk groups, is critical to long-term oral health across the life course.[8]

There is a well-demonstrated association between caries experience and poor academic performance, however, the complexities of this association have not been explored.[9] It has been inferred that missed schooling due to dental pain or dental appointments is a causative factor; however, few studies explore the educational development of young children,[10-14] before school absence is likely to have had an impact. There are no studies in the UK that have investigated this association[9] and there are obvious confounders, such as socio-economic status.[15,16] In wider literature examining dental health and education outcomes, school attendance is sometimes used as a proxy for academic performance,[17,18] but the validity of this measure is uncertain. There have been no studies to date examining the association between caries experience on young children's school readiness.[9]

School readiness is a term used to describe the likely ease with which a child will transition to formal schooling. It is assessed through indicators of intellectual, social and physical development as measured in the Early Years Foundation Stage Profile (EYFSP).[19] EYFSP is a statutory assessment completed by teaching professionals in England during children's last term of reception schooling (at 4–5 years old) before entering curriculum-based education. It comprehensively evaluates a child's development in relation to 12 learning goals in five key learning areas, called the 'Good Level of Development'. It is strongly influenced by the child's earlier experiences, the home environment and parenting ability.[20] Performing well in the EYFSP is also strongly correlated with academic performance at the end of Key Stage 1, following 2 years of formal classroom-based learning.[21] Moreover, recent research has shown the EYFSP has additional utility, such as identifying children with undiagnosed neurodevelopmental disorders.[22]

The Oral Health Survey of 5-year-olds (OHS5) is a biennial survey of children previously undertaken by Public Health England.[23] The national epidemiology programme is used to estimate fluctuations in caries rates and monitor health inequalities on a national, regional, and local level. In the most recent survey, nearly a quarter of children had caries by the age of five, but this figure increased to 30%–50% in more deprived areas of the country, such as Bradford, where this study is situated.[23] There has been no significant reduction in caries prevalence or severity since 2017, and no reduction in oral health inequalities since 2015.[23]

Data from the OHS5 and EYPS were available for some children enrolled in the Born in Bradford (BiB) birth cohort. BiB is a world-leading longitudinal study established in a deprived, diverse, population in Northern England.[24] The rich data gathered by the study has allowed study of the health and development of children during gestation, childhood and beyond. It has become a major source of new evidence to inform policy change.[25,26] Understanding which children are most susceptible to caries is essential to optimisimg the use of finite resources and focus interventions, for the greatest benefit, on those most in need.[27,28]

Combining routinely collected datasets provides valuable insight often not possible with traditional research methods, obtaining findings with an increased efficiency, volume and accuracy.[29] Linking dental data with other medical, educational, environmental and socio-economic sources unlocks the possibility of addressing the root causes of health inequalities, saving time and money for population benefit. The aim of this study was to describe the association between caries experience and school readiness in 5-year-old children.

2 | METHODS

2.1 | Data Sources

This study analysed data obtained from two datasets, the BiB prospective birth cohort study[24] and the OHS5 2015 and 2017.[30,31]

2.1.1 | BiB birth cohort

Detailed information was collected from women during pregnancy and during multiple follow-up observations throughout the lives of the children in the cohort.[32] This included the children's educational records and EYFSP data. All participants within the study were consented for linkage of their BiB data with other health datasets.[33,34]

2.1.2 | Oral Health Survey of 5-year-old Children 2015/17

The survey population was defined as all children attending state-funded mainstream schools in England who were aged five years old at the time of data collection.[30] A stratified sampling framework was applied across the Bradford local authority area.[35] Examinations were conducted by trained and calibrated clinicians using the British Association for the Study of Community Dentistry (BASCD) standards for sampling and clinical assessment.[36,37] A visual examination was carried out using a dental mirror, cotton wool and 4000 lux lighting.[38]

2.1.3 | Data linkage

Following ethical approval (16/YH/0047) and parental consent, children participating in the OHS5 and BiB cohorts were linked. Further details in respect to the methodology, pseudonymisation, secure data transfer and the data sharing agreement are described in an earlier research paper.[33]

2.2 | Measures

2.2.1 | Demographics

BiB education records included demographic information such as sex, ethnicity, special educational needs, and whether the child was receiving Free School Meals (FSM), a measure of socioeconomic deprivation. Ethnicity was grouped into White British, Pakistani and 'all others'. Missing demographic data from academic Year 1 was populated with data from Year 2 records, when available.

2.2.2 | School readiness

The measure of school readiness, EYFSP, was taken from the education records of the BiB cohort. School readiness was assessed in relation to 12 'Learning Goals' across five key learning areas: (i) Communication and Language Development, (ii) Literacy, (iii) Mathematics, (iv) Physical Development and (v) Personal, Social and Emotional Development (Table 1). For each learning goal, children were rated as 'emerging' (below expected), 'expected', 'exceeding' or 'absent for long periods or recently arrived'. Children that achieve 'expected' or 'exceeding' on all learning goals are identified as having a 'Good Level of Development' and are widely considered to be school ready.[39,40] For the purposes of this study the 'absent for long periods or recently arrived' was considered a missing result.[41]

TABLE 1 The Early Years Foundation Stage Profile (EYFSP) outlines expectations for a 'Good Level of Development' in 5 key learning areas with 12 learning goals.

Learning Areas[4]	Learning Goals[11]
(i) Communication and language	Listening and attention Understanding Speaking
(ii) Literacy	Reading Writing
(iii) Mathematics	Number Shape, space and measures
(iv) Physical development	Moving and handling Health and self-care
(v) Personal, social and emotional development	Self-confidence and self-awareness Managing behaviour and feelings Making relationships

Note: Each learning goal is made up of a series of skills and activities. For each goal, teachers categorize the child as 'emerging' (underperforming), 'expected', or 'exceeding' based on their ability.

2.2.3 | Caries experience

The primary outcome variable, caries experience, was taken from the OHS5 2015 and 2017.[23] The survey details $d_3$mft scores for each participant, which is an aggregate of visually obvious decay into dentine (d_3t), missing teeth due to decay (mt) and filled teeth due to decay (ft). Children with a $d_3$mft score of 0 were recorded as having no caries experience, and children with $d_3$mft >0 were recorded as having caries experience.

2.2.4 | Data analysis

The prevalence of caries experience within the sample population was calculated and stratified by the demographic variables and EYFSP learning areas (i–v). Unadjusted odds ratios and statistical significance for each individual variable were established by fitting univariable logistic regression models. Cramer's V statistics were calculated to determine the degree of covariance between each combination of the variables. Variables that showed a positive association ($p < .05$) with caries experience and a low Cramer's V were analysed using multivariable/adjusted logistic regression models. Variables that showed a high Cramer's V covariance were analysed in separate logistic regression models to avoid potentially problematic parameter estimates. Only parameter estimates with a student's *t*-test value of 0.05 or lower were reported in the results.

3 | RESULTS

Between March 2007 and November 2010, 12 453 women with 13 776 pregnancies were recruited from Bradford Royal Infirmary maternity unit.[24] The OHS5 was conducted across primary schools in the Bradford local authority area with 1011 children examined in 2015 and 1287 children in 2017. The study population comprised of 354 (2.5%) BiB children who were also participants of the OHS5.

3.1 | Sample characteristics

Table 2 displays the characteristics of the sample. Most children were male (53%), of Pakistani heritage (48%), did not receive FSMs (81%) and were not formally diagnosed with a SEN (91%). The sample was comparative to the wider BiB cohort in terms of sex (51% male), south Asian ethnicity (53%) and number of children not receiving FSMs (79%). The number of children with Special Educational Needs

TABLE 2 Characteristics of the sample as defined by demographic variables, Early Years Foundation Stage Profile (EYFSP) key learning areas and missing values.

	Missing	Value	Overall, *n* (%)	No caries, *n* (%)	Caries, *n* (%)
n			354	194	160
Sex	0	Female	166 (46.9)	96 (49.5)	70 (43.8)
		Male	188 (53.1)	98 (50.5)	90 (56.2)
Ethnicity	0	Pakistani	170 (48.0)	86 (44.3)	84 (52.5)
		White British	104 (29.4)	65 (33.5)	39 (24.4)
		Other	80 (22.6)	43 (22.2)	37 (23.1)
Free School Meals	5	No	283 (81.1)	169 (88.0)	114 (72.6)
		Yes	66 (18.9)	23 (12.0)	43 (27.4)
Special Educational Needs	7	No	315 (90.8)	174 (91.1)	141 (90.4)
		Yes	32 (9.2)	17 (8.9)	15 (9.6)
(i) Communication: Overall	1	Emerging	84 (23.8)	35 (18.0)	49 (30.8)
		Expected	227 (64.3)	127 (65.5)	100 (62.9)
		Exceeding	42 (11.9)	32 (16.5)	10 (6.3)
(ii) Literacy: Overall	1	Emerging	122 (34.6)	50 (25.8)	72 (45.3)
		Expected	201 (56.9)	118 (60.8)	83 (52.2)
		Exceeding	30 (8.5)	26 (13.4)	4 (2.5)
(iii) Mathematics: Overall	1	Emerging	114 (32.3)	48 (24.7)	66 (41.5)
		Expected	213 (60.3)	124 (63.9)	89 (56.0)
		Exceeding	26 (7.4)	22 (11.3)	4 (2.5)
(iv) Physical: Overall	1	Emerging	60 (17.0)	26 (13.4)	34 (21.4)
		Expected	261 (73.9)	143 (73.7)	118 (74.2)
		Exceeding	32 (9.1)	25 (12.9)	7 (4.4)
(v) Personal, social and emotional development: Overall	1	Emerging	71 (20.1)	26 (13.4)	45 (28.3)
		Expected	253 (71.7)	143 (73.7)	110 (69.2)
		Exceeding	29 (8.2)	25 (12.9)	4 (2.5)

(9%) was lower than the BiB cohort (20%) and wider Bradford population (16%). Further comparison is given in Appendix S1. Most children reached an 'expected' level in the key learning areas. Entries with missing values (17 data points from eight participants) were omitted from the analysis, leaving a total of 346 complete entries for univariable/multivariable modelling. The prevalence of caries experience was 45% ($d_3$mft >0).

3.2 | Caries experience and school readiness

Table 3 displays the stratified counts and unadjusted odds ratios for school readiness and caries experience. Among the demographic variables, receiving FSMs (OR 2.80, 95% CI 1.60–4.91) was the only positively associated variable. Children 'emerging' in learning areas (i, ii, iii, v) had higher odds of experiencing caries when compared to those achieving 'expected' scores. Children that 'exceeded' learning areas (i, ii, iii, v) had lower odds of experiencing caries. 'Physical' (iv) was the only non-significant learning area.

3.3 | Caries experience and school readiness, adjusted for socioeconomic status

Figure 1 shows a heatmap of the Cramers V statistics for each of the demographic and EYFSP learning areas. It demonstrated that EYFSP learning areas shared a significant collinearity and, as such, were all considered separately when fitting adjusted or multivariable logistic regression models. Of the demographic variables, only FSMs were positively associated with caries status; thus, the separate EYFSP learning areas were adjusted for this only.

Table 4 shows the adjusted odds for the logistic regression models with association to caries experience. Except for 'emerging' communication (i), the adjusted models demonstrate a positive association between learning areas and caries experience. Children 'emerging' in learning areas (ii, iii, v) had higher odds of caries experience, ranging from 1.6 to 2.2 (95% CI: 1.09–3.76). The odds of experiencing caries reduced when 'exceeding' learning areas (i, ii, iii, v) ranging between a 2.3- and 4-fold decrease (95% CI: 0.08–0.93).

TABLE 3 Unadjusted odds for caries experience related to participant demographics and Early Years Foundation Stage Profile (EYFSP) key learning areas.

		Unadjusted Odds, (95% CI)
Male	No	1 (baseline)
	Yes	1.27 (0.83, 1.94)
Ethnicity	Other	1 (baseline)
	Pakistani	1.12 (0.65, 1.94)
	White British	0.71 (0.39, 1.29)
Free School Meals	No	1 (baseline)
	Yes	2.80 (1.60, 4.91)
Special Educational Needs	No	1 (baseline)
	Yes	1.10 (0.53, 2.27)
(i) Communication: Overall	Emerging	1.75 (1.05, 2.92)
	Expected	1 (baseline)
	Exceeding	0.40 (0.19, 0.85)
(ii) Literature: Overall	Emerging	2.04 (1.29, 3.24)
	Expected	1 (baseline)
	Exceeding	0.22 (0.07, 0.66)
(iii) Mathematics: Overall	Emerging	1.90 (1.20, 3.03)
	Expected	1 (baseline)
	Exceeding	0.26 (0.085, 0.78)
(iv) Physical: Overall	Emerging	1.61 (0.91, 2.83)
	Expected	1 (baseline)
	Exceeding	0.34 (0.14, 0.82)
(v) Personal, social and emotional development: Overall	Emerging	2.29 (1.33, 3.94)
	Expected	1 (baseline)
	Exceeding	0.21 (0.07, 0.63)

4 | DISCUSSION

Children who are not school ready have higher odds of experiencing caries. This association was apparent across multiple learning areas (i, ii, iii, v) and persisted across ability levels. Children 'emerging' (below expected) in learning areas (ii, iii, v) had higher odds of experiencing caries. This association was mirrored with lower odds of experiencing caries for children 'exceeding' in learning areas (i, ii, iii, v). 'Physical' (iv) showed no association with caries experience; however, the validity of the 'Physical' learning area has been questioned, with teachers reporting limited confidence making movement skills assessments using subjective descriptors.[42]

The EYFSP is a validated framework that holistically assesses children's school readiness before formal classroom-based education.[43] Critically, EYFSP is a routinely administered educational instrument, not reliant on parental engagement, and since its inception 7.5 million children have been assessed. In addition, the use of EYFSP to identify children with undiagnosed neurodevelopmental disorders has also been demonstrated.[22] Internationally, several other countries have developed similar measures of school readiness.[44,45] The finding of interdependence between the learning areas (Figure 1) is consistent with other literature,[21] suggesting that good performance in non-academic areas is associated with better ability to engage with academic classroom activities. While the exact mechanism is uncertain, the study demonstrates further utility of the EYFSP.

The timing of the research, predating the sequelae of caries, indicates poor academic outcomes are not causal through absenteeism due to oral problems, as has been previously suggested.[46,47] Further evidence in the field is emerging to support this; however, educational measures can be unvalidated, such as parental-reported academic attainment.[16] A similar study carried out in preschool children in Southern India mirrored this study's findings, however, did not benefit from an already-collected dental data set.[48] The opportunities afforded by birth cohorts allow novel associations to be uncovered and explored with a rapidity and ease not possible with traditional research methods.

There was a positive association between school readiness and caries experience, which was independent of socio-economic status. This indicates a separate factor, or factors, at play. Parental engagement, irrespective of other confounders, has been implicated as a factor in both academic performance and oral health practices.[49,50] A Brazilian study also identified an independent link between home environment and oral health when adjusting for socio-economic status using self-report measures in older teenagers.[51] Further research is required to tease out these causal patterns.

The study population was largely representative of the BiB cohort; however, a higher prevalence of caries experience was seen for BiB children (45%) compared to the Bradford Metropolitan District (36%). The BiB cohort was recruited from a maternity unit within Bradford city, an area of increased deprivation in comparison to the wider Bradford borough. The diverse and deprived study population provides a unique opportunity to explore early-life indicators of poor health outcomes within a population of multiple vulnerabilities. The number of children with special educational needs was lower than the wider Bradford population, reflecting the fact

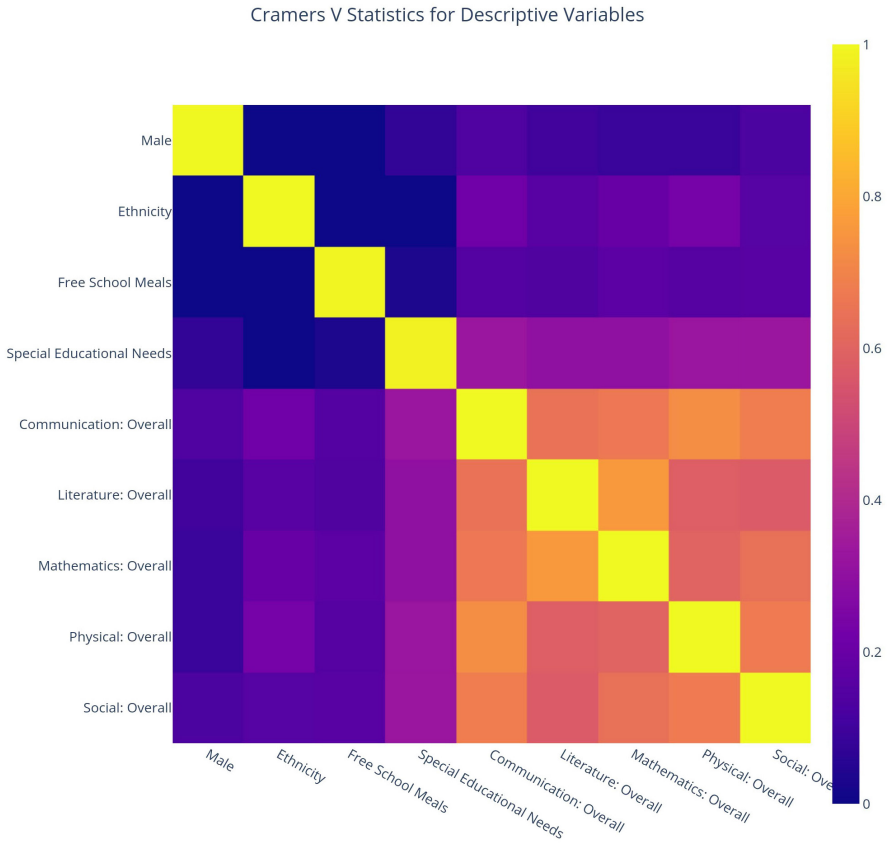

FIGURE 1 Cramer's V statistics heatmap for every combination of the descriptive variables. Statistics range from 0 (no correlation – blue) to 1 (perfect correlation – yellow). Note the block of brighter/more yellow colours in the bottom right, indicating the high covariance between each of the EYFS scores.

TABLE 4 Odds ratios for caries experience and Early Years Foundation Stage Profile (EYFSP) learning areas (i, ii, iii and v), adjusted for eligibility for Free School Meals.

		Adjusted odds OR (95% CI)
(i) Communication: Overall	Emerging	1.61 (0.96, 2.72)
	Expected	1 (baseline)
	Exceeding	0.43 (0.20, 0.93)
	Free School Meals	2.48 (1.40, 4.39)
(ii) Literature: Overall	Emerging	1.94 (1.22, 3.10)
	Expected	1 (baseline)
	Exceeding	0.25 (0.08, 0.75)
	Free School Meals	2.39 (1.35, 4.25)
(iii) Mathematics: Overall	Emerging	1.74 (1.09, 2.80)
	Expected	1 (baseline)
	Exceeding	0.28 (0.09, 0.85)
	Free School Meals	2.39 (1.35, 4.24)
(v) Personal, social and emotional development: Overall	Emerging	2.16 (1.24, 3.76)
	Expected	1 (baseline)
	Exceeding	0.24 (0.08, 0.74)
	Free School Meals	2.35 (1.33, 4.16)

that only mainstream schools are included in the OHS5. Despite this, caries rates were much higher than the regional average.

There were limitations of the datasets used in this study. Public Health England concede the OHS5 of is likely to be an underestimate of caries rates due to the positive consent process, mainstream-only school inclusion, and caries detection without the use of radiographs.[23] Owing to missing data, demographic information from the children's second year of schooling was used in the data analysis; however, observations from the wider BiB dataset have demonstrated there are not significant changes between academic years. Children absent for long periods or with missing data were excluded, but due to the extremely small number (eight), this was unlikely to have influenced the results. A great strength of the BiB birth cohort is its diverse sample and the inclusion of underserved groups. However, replication of this study is needed in different populations to demonstrate consistent and generalizable findings.

EYFSP shows potential, with further research, as a prediction tool to identify children at higher risk of caries. With the use

of causal inference methodologies, it may be possible to tease out causal effects that will improve the targeting of evidenced-based oral health interventions at a school, class or child level. These interventions include supervised-toothbrushing programmes or support worker home visits,[52] alongside upstream measures to address the wider determinans of health inequalities.

5 | CONCLUSION

This is the first study to explore the association between caries experience and school readiness using a holistic assessment tool. The association between caries and school readiness was found across different learning areas and was comparable and independent of socio-economic status. The findings indicate absenteeism due to oral problems is not a causative factor. This study highlights the value and limitations of linked datasets and the potential for collaboration between health and education sectors. EYFSP shows potential to enhance the targeting of preventive interventions at a child, class or school-level.

AUTHOR CONTRIBUTIONS

PD was principal supervisor on the project. EG led project development and writing of the manuscript with major contributions from SR, KGB, SB and PD. SR lead the data analysis. All authors including SR, KGB, SB and PD have had the opportunity to read, contribute and approve the manuscript.

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DATA AVAILABILITY STATEMENT

The data are not publicly available due to ethical restrictions and are available on request. Further information on requests for data can be found at: https://borninbradford.nhs.uk/research/guidance-for-collaborators.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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