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Obesity and dental caries in childhood: trends in prevalence and socioeconomic inequalities—a multicohort population-wide data linkage study

Ryan Stewart ,[1,2] David I Conway,[1] Lorna M D Macpherson,[1] Andrea Sherriff[1]

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[1]School of Medicine, Dentistry and Nursing, College of Medical, Veterinary and Life Sciences, University of Glasgow, Glasgow, UK
[2]Department of Mathematics & Statistics, University of Strathclyde, Glasgow, UK

Correspondence to
Professor Andrea Sherriff; andrea.sherriff@glasgow.ac.uk

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ABSTRACT

Objectives To quantify levels of coexisting obesity and caries experience in children in Scotland, and any associated socioeconomic inequalities over the years 2011/2012–2017/2018.

Design A multicohort population-wide data linkage study.

Setting Local authority primary schools in Scotland.

Patients 335 361 primary 1 (approximately 5 years old) schoolchildren in Scotland between 2011/2012 and 2017/2018.

Main outcome measures Prevalence and inequalities in coexisting caries and obesity.

Results The prevalence of coexisting obesity and caries experience was 3.4% (n=11 494 of 335 361) and did not change over the 7 years. Children living in the 20% most deprived areas had more than sixfold greater odds of coexisting obesity and caries experience than children from the 20% least deprived areas (adjusted OR=6.63 (95% CI=6.16 to 7.14; p<0.001)). There was a large persistent socioeconomic gradient across the Scottish Index of Multiple Deprivation groups, with the Slope and Relative Indices of Inequality remaining unchanged over the 7 cohort years.

Conclusions Despite improvements in oral health in children in Scotland, the prevalence of coexisting obesity and caries experience has remained static, with large persistent inequalities. These conditions are likely to signal increased risk of chronic conditions including multimorbidity in adulthood and therefore early identification of children most at risk and timely intervention tackling common risk factors should be developed and evaluated.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Systematic reviews provide conflicting evidence on the association between obesity and caries.
⇒ Some studies have previously estimated the prevalence of coexisting obesity and caries, although using small sample sizes or not recently.

WHAT THIS STUDY ADDS

⇒ Sophisticated analyses of contemporary large administrative and health datasets collected routinely, using measures of absolute and relative inequalities.
⇒ First time a study of this size has reported on inequalities in prevalence of coexisting obesity and caries using Scottish data.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Early intervention, using established multiagency programmes which can collaborate to tackle non-communicable diseases as recommended by the WHO, is crucial to prevent coexisting conditions.
⇒ Ensuring national programmes reach children likely to develop coexisting obesity and caries experience and their families is essential for providing necessary support.

BACKGROUND

Globally, inequalities in child oral health and childhood obesity pose a major public health challenge. Dental caries in primary dentition affects over 514 million children[1] and 38.2 million children under the age of 5 years are affected by overweight or obesity,[2] burdening healthcare systems and society.[3 4] These conditions harm early-life health, quality of life and future education,[5 6] particularly affecting vulnerable groups due to socioeconomic inequalities. As a consequence, an understanding of the drivers/determinants underpinning these inequalities is a strategic goal of the WHO.[1] Some studies identify an association between childhood caries and obesity, likely due to the shared risk factors such as high sugar consumption.[7–9] Systematic reviews provide conflicting information on the association between caries and obesity with the true relationship unknown due to methodological limitations of study designs, generally small sample sizes. Dental caries and obesity manifest early in childhood, share common risk factors, are sufficiently prevalent and in combination, could signal higher risk of multimorbidity in adulthood impacting quality of life and life expectancy, and challenging healthcare systems. Early identification and intervention in high-risk children could help prevent chronic conditions in later life. This study aims to quantify coexisting caries and obesity in children in Scotland between 2011/2012 and 2017/2018 and examine associated socioeconomic inequalities to identify the prevalence of children requiring further intervention and socioeconomic groups that require further support.

METHODS

Study design and participants

Data from seven population-wide birth cohorts of children in primary 1 between 2011/2012 and

2017/2018 in Scotland were collated from two routine health databases held by Public Health Scotland (PHS).

Databases

1. National Dental Inspection Programme (NDIP) database[10] annually surveys oral health in primary 1 (approximately 5 years old) children in local authority schools on an opt-out basis. Trained and standardised dental teams assess each child's mouth and teeth.
2. Child Health Surveillance Programme–School (CHSP-S)[11] collects data from Scotland's annual body mass index (BMI) survey for primary 1 children in local authority schools on an opt-out basis, with optional participation for some private schools. Health professionals, typically school nursing teams, follow Royal College of Paediatrics and Child Health guidelines[12] for reviews conducted throughout the academic year.

Definitions

Obvious caries experience (yes/no) was defined as the child having one or more of: abscess or infection, gross caries, obviously carious (into dentine) permanent or primary tooth, missing primary molar, evidence of restorations.

BMI SD scores (SDS) ($\text{BMI} = \frac{\text{weight (kg)}}{\text{height (m)}^2}$) were computed using Cole's UK 1990 references.[13] Using epidemiological age-specific and sex-specific cut-offs, children in ≥95th centile (SDS circa ≥1.645) had obesity, centiles ≥85th and <95th (SDS circa ≥1.036 and 1.645) had overweight, centiles >2nd and <85th (SDS circa >−2 and <1.036) had healthy weight, and <2nd centile (SDS circa ≤−2) had underweight.

Children with both obesity and obvious caries experience were categorised as having coexisting obesity and caries experience and were compared with those with neither condition. Those with either condition were considered, though not reported here (see online supplemental figures 1–4).

Area-based socioeconomic deprivation, based on the Scottish Index of Multiple Deprivation (SIMD) at a national level,[14] used child home postcodes. SIMD assesses deprivation through 38 indicators across seven domains. The list of small areas (data zones) was ordered by deprivation and split into fifths. SIMD 1 represents the most deprived 20% and SIMD 5 represents the least deprived 20%. SIMD 2012[15] was used for academic years 2011/2012–2013/2014 and SIMD 2016[14] for 2014/2015–2017/2018 following PHS and CHSP-S guidelines.[11 16]

Table 1 Description of cohorts according to caries experience and body mass index (BMI) status

	All children		Dental				BMI status							
			Caries experience		No caries experience		Underweight		Healthy weight		Overweight		Obesity	
Characteristic	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Scotland	335 361	100	102 388	30.5	232 973	69.5	3350	1.1	257 848	76.9	41 003	12.2	32 960	9.8
Dental														
Caries experience	102 388	30.5	–	–	–	–	1157	1.1	76 806	75.0	12 931	12.6	11 494	11.2
No caries experience	232 973	69.5	–	–	–	–	2393	1.0	181 042	77.7	28 071	12.0	21 466	9.2
BMI status														
Underweight	3350	1.1	1157	32.6	2393	67.4	–	–	–	–	–	–	–	–
Healthy weight	257 848	76.9	76 806	29.8	181 042	70.2	–	–	–	–	–	–	–	–
Overweight	41 003	12.2	12 931	31.5	28 072	68.5	–	–	–	–	–	–	–	–
Obesity	32 960	9.8	11 494	34.9	21 466	65.1	–	–	–	–	–	–	–	–
SIMD														
1 (MD 20%)	77 580	23.1	35 656	46.0	41 924	54.0	856	1.1	56 955	73.4	10 126	13.1	9643	12.4
2	67 458	20.1	24 363	36.1	43 095	63.9	803	1.2	50 505	74.9	8601	12.8	7549	11.2
3	62 572	18.7	17 714	28.3	44 858	71.7	665	1.1	48 042	76.8	7775	12.4	6090	9.7
4	65 054	19.4	14 313	22.0	50 741	78.0	595	0.9	51 308	78.9	7702	11.8	5449	8.4
5 (LD 20%)	62 697	18.7	10 342	16.5	52 355	83.5	631	1.0	51 038	81.4	6799	10.8	4229	6.8
Sex														
Male	170 745	50.9	54 040	31.6	116 705	68.4	2310	1.4	130 115	76.2	21 073	12.3	17 247	10.1
Female	164 616	49.1	48 348	29.4	116 268	70.6	1240	0.8	127 733	77.6	19 930	12.1	15 713	9.6
Age (years old)														
4	15 383	4.6	4141	26.9	11 242	73.1	138	0.9	11 564	75.2	2097	13.6	1584	10.3
5	291 715	87.0	88 632	30.4	203 083	69.6	3027	1.0	224 279	76.9	35 753	12.3	28 656	9.8
6	28 263	8.4	9615	34.0	18 648	66.0	385	1.4	22 005	77.9	3153	11.2	2720	9.6
School year														
2011/2012	46 417	13.8	15 162	32.7	31 255	67.3	574	1.2	35 688	76.9	5622	12.1	4533	9.8
2012/2013	48 222	14.4	15 593	32.3	32 629	67.7	530	1.1	37 492	77.7	5771	12.0	4429	9.2
2013/2014	49 369	14.7	15 752	31.9	33 617	68.1	485	1.0	37 792	76.6	6140	12.4	4952	10.0
2014/2015	49 349	14.7	14 457	29.3	34 892	70.7	521	1.1	38 065	77.1	5963	12.1	4800	9.7
2015/2016	47 840	14.3	14 225	29.7	33 615	70.3	516	1.1	36 799	76.9	5841	12.2	4684	9.8
2016/2017	46 334	13.8	13 370	28.9	32 964	71.1	428	0.9	35 372	76.3	5761	12.4	4773	10.3
2017/2018	47 830	14.3	13 829	28.9	34 001	71.1	496	1.0	36 640	76.6	5905	12.3	4789	10.0

LD, least deprived; MD, most deprived; SIMD, Scottish Index of Multiple Deprivation.

Table 2 Descriptive statistics on body mass index SD scores by caries experience

	n	Mean	SD	Median	Min	IQ 1	IQ 3	Max
No caries	232 973	0.31	1.04	0.26	−5.93	−0.35	0.91	5.74
Caries	102 388	0.37	1.10	0.31	−5.98	−0.33	1.00	5.99

Inclusion criteria

The cohort included primary 1 children aged 4.0–7.0 years old, with valid dental and BMI assessments from 2011/2012 to 2017/2018. NDIP had 401 054 children, but after exclusions (false ID matches, no examinations, age, missing deprivation, invalid outcomes, repeat examinations, duplicates), it comprised of 357 798 children (online supplemental figure 5). CHSP-S initially had 374 067 children. After exclusion (age, extreme BMI/height/weight SDS, missing deprivation), it comprised of 373 189 children (online supplemental figure 5). Linking the databases gave a cohort of 335 361 children who had a valid NDIP and CHSP-S assessment.

Statistical analysis

Analyses occurred in the National Health Service National Safe Haven,[17] adhering to best practice guidance.[18 19] R V.3.6.1[20] was employed for data cleaning and statistical analysis. Trends were examined in coexisting obesity and caries experience (defined as coexisting conditions) in children over 7 academic years (2011/2012–2017/2018) using line graphs, considering sex and area-based deprivation (SIMD).

To address inequalities comprehensively, Slope Index of Inequality (SII) and Relative Index of Inequality (RII) were calculated with 95% CIs to quantify absolute and relative inequalities in the prevalence of coexisting conditions. SII and RII were calculated via additive and multiplicative Poisson regression, respectively. The coexisting conditions rate (n=11 494) was used as the dependent variable, with the midpoint of the cumulative population in each socioeconomic fifth (measured by SIMD) as the independent variable, employing robust SEs.[21] SII measures absolute inequality in the rate between those from the most and least deprived areas in terms of a rate difference, while RII represents the ratio of coexisting conditions in those from the most deprived areas compared with those from the least deprived areas.[22] To assess trends, linear regression was performed, regressing SII and RII estimates against academic years as a continuous variable.

To assess coexisting condition risk over time, we employed a multinomial logistic regression model with four mutually exclusive outcomes, where coexisting conditions (n=11 494), caries experience only (n=90 895) and obesity only (n=21 466) as outcomes, compared with neither condition (n=211 506). This method provided a 'clean' reference category of neither condition rather than a 'not caries or obesity' reference category in a binary logistic model which could dilute the main contrast of interest. This produced parameter estimates which compared coexisting versus neither condition, caries experience only versus neither condition and obesity only versus neither condition. We used categorical independent variables: area-based deprivation (SIMD), sex, age and academic year. The final model included only the main effects of these variables. Adjusted ORs (aORs) were calculated by exponentiating model estimates, and 95% CIs were presented.

RESULTS

A total of 335 361 children with valid data on caries experience (yes/no) and BMI status (underweight, healthy weight, overweight, obesity) were available. The seven cohorts represented 83.2% (n=46 417 of 55 769), 84.6% (n=48 222 of 57 021), 83.0% (n=49 369 of 59 490), 82.5% (n=49 349 of 59 796),

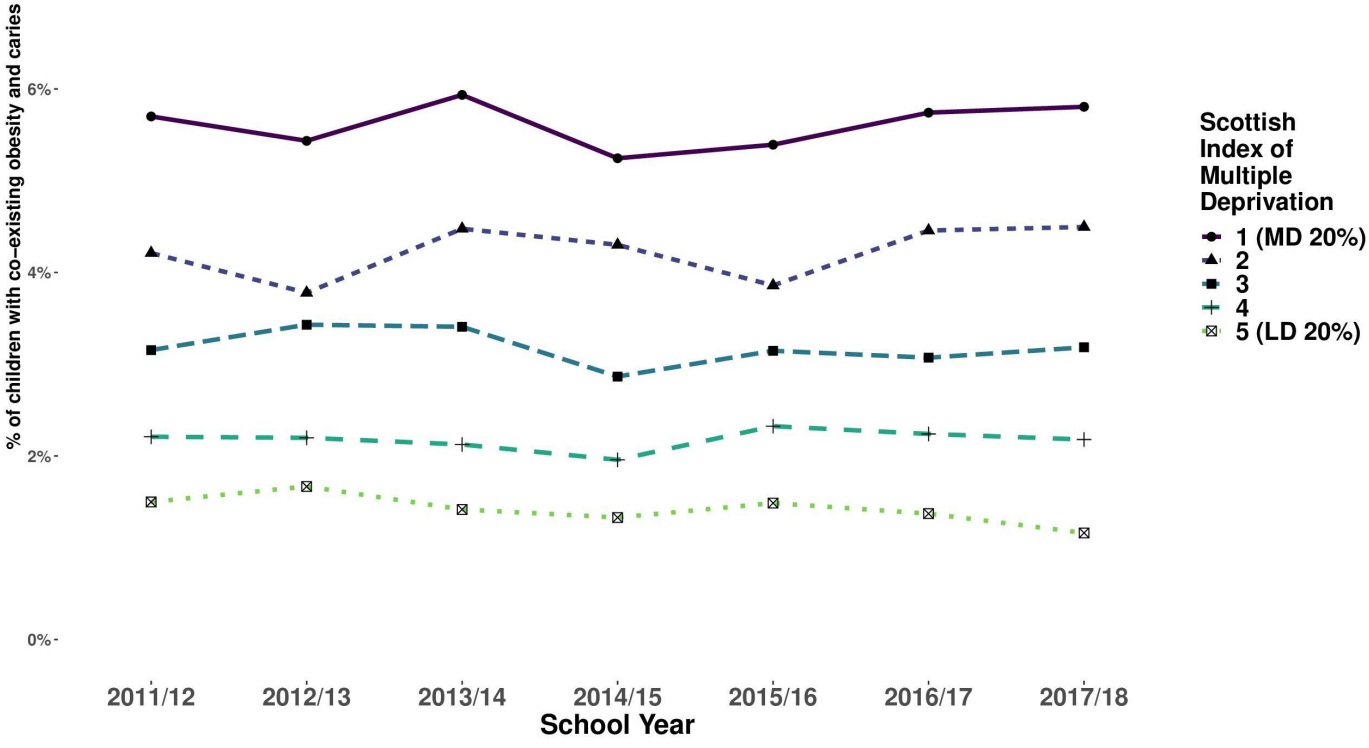

Figure 1 Prevalence of coexisting obesity and caries experience in 5-year-old schoolchildren in Scotland split by area-based deprivation (online supplemental table 1). LD 20%, least deprived 20%; MD 20%, most deprived 20%.

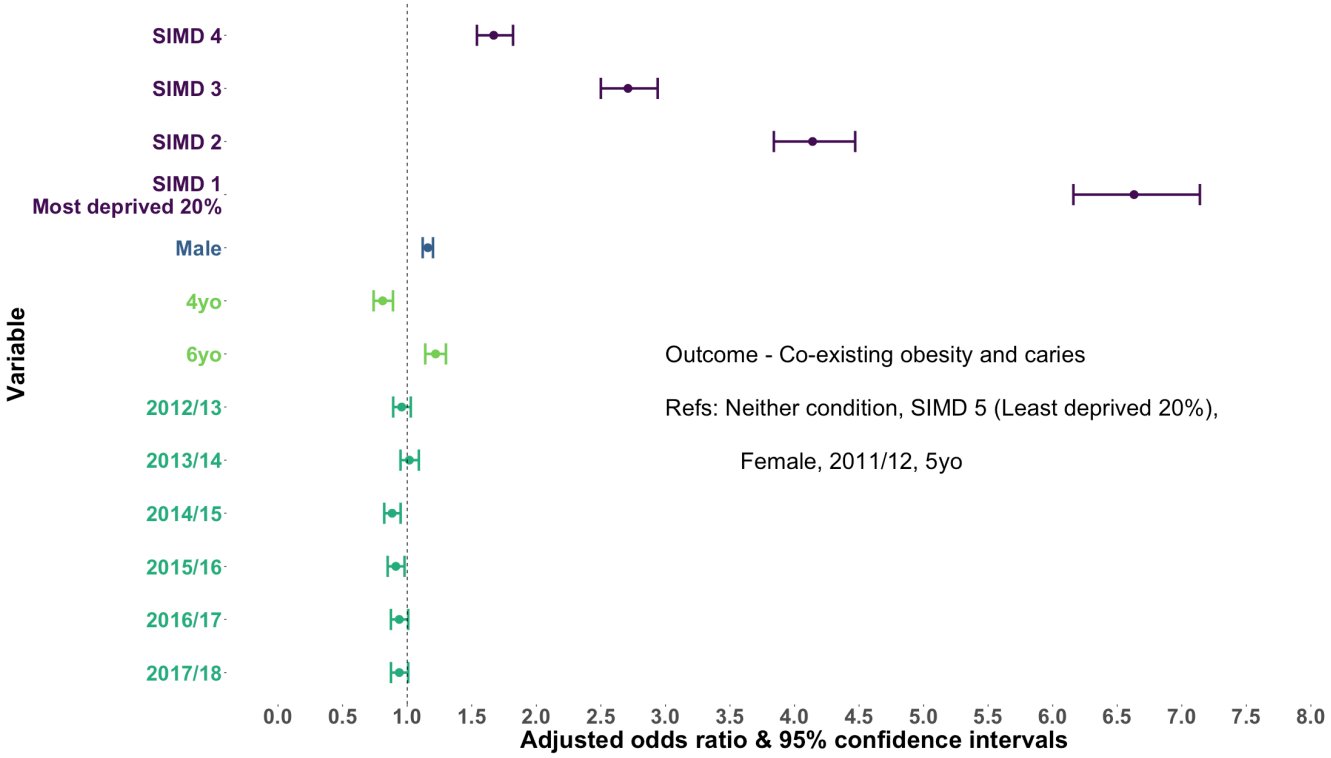

Figure 2 Adjusted ORs and 95% CIs for the risk of experiencing coexisting obesity and caries experience compared with experiencing neither condition for sex, age, academic year and socioeconomic deprivation (SIMD). SIMD, Scottish Index of Multiple Deprivation; yo, years old.

81.8% (n=47 840 of 58 497), 75.1% (n=46 334 of 61 695) and 79.7% (n=47 830 of 60 001) of the National Records for Scotland (NRS) population estimate[23] for the 7 academic years, respectively. The reduction in population captured was distributed equally across the socioeconomic scale and for each sex, thus should have no effect on the results. The cohorts had a balanced sex split of 50.9% (n=170 745 of 335 361) males and 49.1% (n=164 616 of 335 361) females (table 1). The SIMD distribution favoured SIMD 1 (most deprived; 23.1%) and had the fewest in SIMD 5 (least deprived; 18.7%), aligning with NRS birth records.[23] Caries experience prevalence declined since 2011/2012, while obesity prevalence remained steady, both exhibiting socioeconomic gradients. Children with caries experience had a higher likelihood of obesity than children with no caries experience (11.2% vs 9.2%), and among children with obesity, 34.9% had caries experience vs 29.8% with a healthy BMI (table 1).

Overall, the mean BMI SDS was 0.33. In children with caries experience, it was slightly higher (0.37) than those without caries experience (0.31) (table 2). Children with caries had a wider range of BMI SDS values, with a lower minimum and higher maximum (table 2).

Prevalence of coexisting obesity and caries experience

Overall, coexisting conditions prevalence was 3.4% (n=11 494 of 335 361), which remained stable across the 7 academic years, with a 63.1% (n=211 506 of 335 361) prevalence of children with neither condition, which slightly increased over the 7 years. The trend is coexisting conditions held for both sexes with males and females maintaining 3.7% (2011/2012 n=870 of 23 717; 2017/2018 n=905 of 24 452) and 3.2% (2011/2012 n=736 of 22 700; 2017/2018 n=744 of 23 378) prevalence, respectively, in both 2011/2012 and 2017/2018 (online supplemental table 1). In 2011/2012, prevalence of coexisting conditions was 5.7% (n=605 of 10 614) in children from the most deprived areas (SIMD 1) vs 1.5% (n=126 of 8403) in children from the least deprived areas (SIMD 5), a 4.2% (n=479) difference. In 2017/2018, this gap widened to 4.6% (n=515), with a prevalence of 5.8% (n=624 of 10 749) in SIMD 1 and 1.2% (n=109 of 9381) in SIMD 5 (figure 1). Prevalence slightly increased with age, with 3.2% (n=493 of 15 383) at age 4, 3.4% (n=9960 of 291 715) at age 5 and 3.7% (n=1041 of 28 263) at age 6 years (online supplemental table 1).

Inequalities in coexisting obesity and caries experience

For clarity, we present the results from the multinomial model for coexisting conditions versus neither condition in the main text of the results as the salient findings. For completeness, the other contrasts (caries only vs neither and obesity only vs neither) are provided in the online supplemental material.

In a multivariable multinomial logistic regression model, adjusting for sex, age and academic year, children from the most deprived 20% of areas in Scotland have over six times the odds of coexisting obesity and caries compared with those in the least deprived 20% (aOR=6.63; 95% CI=6.16 to 7.14; p<0.001), showing a gradient across all SIMD fifths (figure 2). Males had slightly higher odds than females (aOR=1.16; 95%CI: 1.12 to 1.20; p<0.001), and odds increased with age (figure 2 and online supplemental table 2).

The absolute and relative indices of inequality for coexisting conditions remained stable, although large (figure 3 and online supplemental table 3). The SII was estimated at 5.0% (95% CI: 4.5% to 5.6%) in 2011/2012 and 5.8% (95% CI: 5.5% to 6.0%) in 2017/2018 (p slope=0.23). The RII was estimated to be 5.05 (95% CI: 4.48 to 5.69) in 2011/2012 and 6.25 (95% CI: 4.50 to 8.69) in 2017/2018, which although not a significant increase (p for slope=0.17), appears to be a rise over the study period.

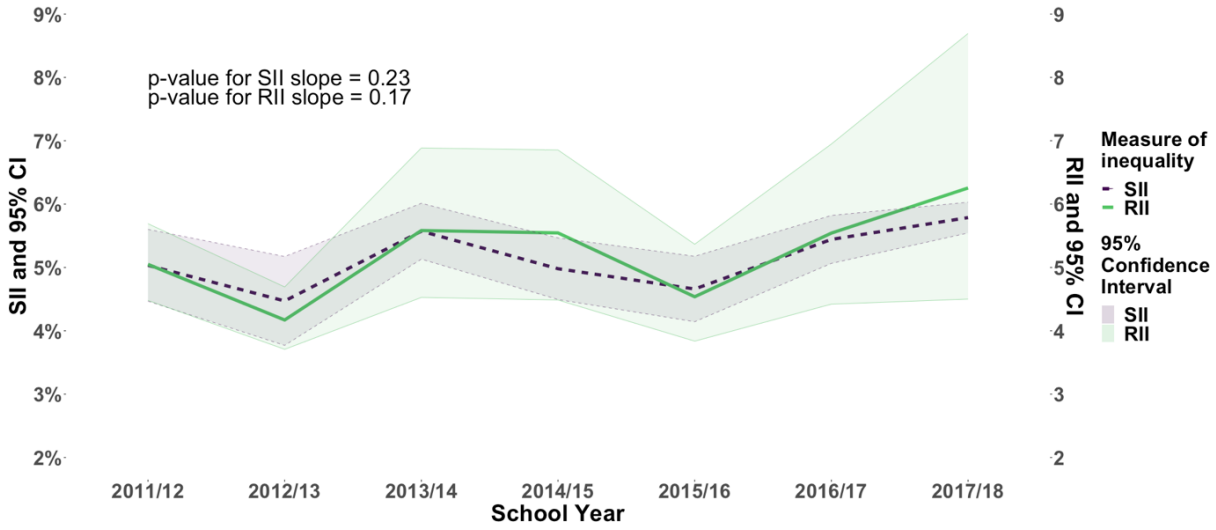

Figure 3 Slope Index of Inequality (SII) and Relative Index of Inequality (RII) for children with coexisting obesity and caries experience.

DISCUSSION

This study revealed a persistent 3.4% prevalence of coexisting childhood obesity and caries experience in Scotland over nearly a decade, despite caries experience rates improving during the same period.[24] These overall figures mask stark inequalities, with children living in the most deprived areas having over six times the odds of having coexisting conditions than those from the least deprived areas, an inequality that has endured over time.

To the best of our knowledge, no other study in Scotland or the UK has continuously examined coexisting conditions over this duration. Public Health England reported a 2.4% prevalence of coexisting conditions in children 5 years old in 2016/2017,[25] lower than the 3.4% in Scotland. However, this discrepancy may stem from differences in consent protocols, with opt-in consent in England versus opt-out in Scotland, possibly favouring less deprived areas.[26 27] A recent PhD thesis, based on the Born in Bradford Study,[28] reported a 3.5% (n=6 of 171) prevalence among children 0–5 years old in 2014/2015,[29] aligning with our findings, though this was a 1-year estimate with varying age groups and a limited sample from a specific area in England.

Few recent global studies have estimated the prevalence of coexisting conditions, with limited comparability. A US study from 2008, using 1999–2002 data, reported a 3.9% (~56 of 1449) prevalence in children 2–5 years old, focused solely on primary dentition.[30] However, given the 9-year gap and US–Scotland differences, comparisons are difficult. A study from Greenland found a 3.8% (14 of 373) prevalence in children with a median age of 6.6 years old (2005–2007 births), with higher caries (57.1%) and lower obesity (5.1%) prevalence than this study.[31] In 2013, in Greece, the prevalence was estimated at 0.5% in 2180 children aged 2.5–5.9 years old, with lower obesity (3.2%) and caries (10.0%), differing substantially from the prevalence identified in Scotland.[32]

This study has found significantly large and consistent socioeconomic inequalities in the prevalence of coexisting conditions during the study period (2011–2018). These children with coexisting conditions have compounded needs and potential preventive interventions using the common risk factor approach could be developed.[33 34] However, this group has not previously been identified as an important target/priority group in Scotland and there is a need to identify the risk predictors for having coexisting conditions in early childhood. To the authors' best knowledge, there are no studies to estimate the inequalities in children with coexisting caries and obesity.

Our study exhibits both strengths and limitations. The data do not encompass all children attending private schools, which constitute around 5% of the student population, although these children are likely to be more affluent and less impacted. The data also only measure children who were in attendance on the day of inspection. Regarding health data, we relied on routine administrative health service data, which come with certain limitations in terms of detail. Obesity can be defined as an accumulation of excess body fat, rather than simply an increase in body weight.[35] Given the challenge of directly measuring body fat in large population-based studies, a high BMI-for-age is commonly employed as an indirect indicator of elevated body fatness.[36] However, relying on BMI-for-age as a substitute leads to a significant underestimation of actual obesity rates compared with a measurement of excessive fatness.[37] This suggests that the true prevalence of obesity in Scotland is likely higher than the reported estimates, which were derived from BMI-for-age calculations. Thus, our presented figures for obesity prevalence among children 5 years old in Scotland are likely conservative. Personal socioeconomic data at the individual level were not available within the regular administrative data. Consequently, we relied on area-based deprivation indicators. This approach has its limitations, as it involves drawing conclusions about individuals based on group-level data (ie, the ecological fallacy) and does not account for variations in individual-level risk factors and disease prevalence within residential areas.[38] However, area-level measures are very commonly used as an indicator of socioeconomic position. These limitations are offset by their broad coverage, high quality and comprehensiveness. In our analysis, we used dental caries outcome data from NDIP. These data, obtained through 'basic' inspections, yielded similar results to data from detailed epidemiological inspections, which encompass more comprehensive information on dental caries experiences ($d_3$mft) and are conducted on a 20% subset of the population by trained and standardised examiners using the criteria established by the British Association of Community Dentistry.[24 39] The prevalence of obvious caries experience in children 5 years old was approximately 30.6% (2016) and 28.9% (2018) based on basic inspections, while it was 30.1% (2016) and 29.6% (2018) from detailed epidemiological inspections.[24] The process of linking

education and health records through probabilistic matching is considered robust and has been previously validated with an accuracy rate of 99%.[40] Our analysis was comprehensive and accounted for key confounding factors such as socioeconomic status and age when evaluating caries and obesity outcomes.

Conclusions

We observed a consistent prevalence of coexisting obesity and caries experience in children in primary 1 (approximately 5 years old) in Scotland from 2011 to 2018, with large stubborn socioeconomic inequalities. These children face heightened risk of future chronic diseases and multimorbidity, bearing economic and societal burdens. Early intervention, using established multiagency programmes which can collaborate to tackle non-communicable diseases as recommended by WHO, is crucial to prevent coexisting conditions. Ensuring national programmes reach children likely to develop coexisting obesity and caries experience and their families is essential for providing necessary support.

X Ryan Stewart @stewart_ryan3

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Contributors AS, LMDM and DC conceived the idea of this study. AS, DC, LMDM and RS designed the study. DC and AS prepared data requests and study approvals and data sharing agreements. RS undertook data management. RS with AS performed analysis and prepared figures and tables. AS and DC prepared first draft of the manuscript. RS prepared further drafts of the manuscript. AS is guarantor.

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Disclaimer The study funder had no role in study design, data collection, data analysis, data interpretation or writing of the report.

Competing interests None declared.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and ethical approval was obtained from the University of Glasgow Ethics Committee (project number: MVLS200150076). This study received approval from the NHS National Services Scotland Privacy Advisory Committee and Public Benefit and Privacy Panel (approval no. 1516-0368). Data are pseudonymised secondary data and so it is not possible for the researchers to contact patients. Approval was allowed to use the data as there is a benefit to the public.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data may be obtained from a third party and are not publicly available. We applied for approval to access, link and analyse the study data within the NHS National Safe Haven environment and undertook information governance training. The data generated, linked and analysed during the study are not publicly available. The data controller for all health data is Public Health Scotland, and researchers can apply to access via email: phs.edris@phs.scot.

ORCID iD

Ryan Stewart http://orcid.org/0000-0001-8450-1491

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