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Childhood Factors and Dental Caries in the Permanent Dentition: Findings of an 8-Year Study Under a Nationwide School Dental Service

Sharon Hui Xuan Tan a,b, Yik-Ying Teoa, Melissa Hui Xian Tan c, Xiaoli Gao a,d*

a Saw Swee Hock School of Public Health, National University of Singapore, Singapore
b Ministry of Health, Singapore
c Health Promotion Board, Singapore
d Faculty of Dentistry, National University of Singapore, Singapore

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ABSTRACT

Objective: This study, using a retrospective analysis of nationwide dental records of school-going children over 8 years, aims to identify childhood factors associated with dental caries incidence in the permanent dentition up to adolescence.

Methods: Students studying in primary and secondary schools in Singapore are eligible for free basic dental care under the nationwide School Dental Service (SDS). All available dental records, general health records, and sociodemographic data from 2009 to 2017 were extracted as anonymised records, for a full cohort of 29,617 students that were enrolled in Primary 1 in 2009. Multiple logistic regression and modified Poisson regression were applied to identify risk factors for caries incidence in the permanent dentition over 8 years.

Results: Caries occurred in the permanent dentition of 9389 (31.7%) students in the 8 years. Risk of caries incidence in the permanent dentition was associated with baseline caries in the primary (risk ratio [RR]: 1.88; 95% CI: 1.81, 1.95) and permanent (RR: 1.54; 95% CI: 1.47, 1.61) dentition, tooth hypoplasia (RR: 1.58; 95% CI: 1.49, 1.68), and poor baseline oral hygiene (RR: 1.07; 95% CI: 1.03, 1.12). Sociodemographic predictors of caries incidence include a lower socioeconomic status, Chinese ethnicity, female gender, and enrolment in nonmainstream schools or schools in the Eastern and Western regions of Singapore.

Conclusions: Both clinical and sociodemographic factors in childhood are associated with caries incidence in the permanent dentition and can be used for structuring dental service provision and identifying caries-susceptible individuals and groups for early prevention and intervention.

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Key words:
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Longitudinal
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Introduction

While many countries provide school-based dental services, few have evaluated the longitudinal oral health outcomes of individuals who undergo a structured school-based dental service programme from childhood to adolescence. Understanding the risk factors for dental caries development among students is important to improve population oral health and reduce health inequalities under the concept of ‘proportionate universalism.’ Beyond a targeted approach to individuals, or directed population approach to subgroups at higher risk, the identification of risk factors associated with caries incidence under a universal oral health programme may aid in the refinement and further development of interventions with gradations in scale and intensity that are proportionate to the needs and level of disadvantage.

Most studies on caries risk among children and adolescents are cross-sectional. Based on cross-sectional studies, demographic and socioeconomic factors such as ethnicity, area of residence, type of school, and maternal level of education are associated with the prevalence of dental caries...
among adolescents. Nonetheless, it is uncertain if these factors are associated with the incidence of or increment in dental caries. Research in caries risk is characterised by an increasing interest in longitudinal studies, especially life course studies. A study among young adolescents found that past caries, incipient caries, the presence of sucrose activity, salivary lactobacilli, and Candida were associated with caries increment over 11 months. A study of 12-year-olds in Sweden found that previous experience of caries and socioeconomic level influenced the risk of developing new caries in 2 years. Another study in Belgium found that oral health-related behaviours such as infrequent toothbrushing and regular intake of sugary drinks were risk factors for caries increment over a 3-year period, while a discriminant function analysis found that lower socioeconomic status (SES) and baseline caries in the primary and permanent dentition predicted the risk of caries increment in children over 4 years. More recently, Warren et al. found that lower maternal education, infrequent toothbrushing, and the female gender were associated with a high caries incidence in adolescence (from 13 to 17 years of age).

Nonetheless, in regard to longitudinal studies, follow-up periods were often relatively short, with few observing caries development from childhood into adolescence. There is thus a need to ascertain if modifiable and nonmodifiable factors in early life have a persistent effect on the risk of caries incidence in the long term. Furthermore, none of the existing studies involve a large-scale, population-wide sample in the context of a school dental service programme. There is a need to further our understanding of the residual impact of risk factors on the oral health of children who undergo standardised dental assessments and receive dental care at regular intervals.

Singapore is a tropical island country located in Southeast Asia. It is a multicultural country with a total population of 5.7 million (as of 2019) consisting of Chinese (74.4%), Malay (13.4%), Indian (9.0%), and others (3.2%). It is the first country in Asia to institute a comprehensive water fluoridation programme covering 100% of the population since 1958. Water fluoridation levels were initially set at 0.7 ppmF, changed to 0.6 ppmF in 1992, and kept at 0.5 ppmF since the start of 2008. The variation across regions was reasonably controlled. In 2015, the average water fluoride level was reported to be 0.47 ppmF and ranged between 0.36 and 0.66 ppmF. There is no nationwide supplemental fluoridation policy beyond community water fluoridation. All students studying in primary and secondary schools (aged 7-18) in Singapore are eligible for free basic dental care under the School Dental Service (SDS) operated by the Health Promotion Board. Preventive oral health programmes such as toothbrushing exercises, plaque disclosing programmes, and dental talks on gum disease are carried out in all schools. Standard clinical oral examinations are scheduled in 6 school years, Primary 1, 2, 4, and 6 and Secondary 1 and 3, corresponding to approximate ages 7, 8, 10, 12, 13, and 15, respectively, for students with parental consent. Across the years, approximately 92%-97% of students in Singapore are enrolled in SDS, of which more than 90% receive oral examinations.

Although risk factors for caries prevalence and caries incidence have been explored in preschool children in Singapore, they have not been examined for older children and adolescents. Reports of “low” mean decayed, missing, or filled teeth (DMFT) counts (<1) among adolescents in Singapore suggest that a substantial proportion of adolescents are caries free (DMFT = 0) in the permanent dentition, and that there may be an unequal distribution of the caries burden. Identifying schoolchildren and adolescents who are susceptible to caries is therefore of paramount importance for targeted and cost-effective caries control in this population.

This study, using data from a full cohort in the nationwide SDS in Singapore, aims to fill the aforementioned knowledge gaps and identify the childhood factors associated with dental caries in adolescence. The identification of risk factors for caries incidence over the schooling years may aid in the refinement of the caries risk classification of students and enhance the risk-based approach and structuring of existing resources to maximise oral health outcomes and address inequalities.

Methods

The study population included students enrolled in Primary 1 in 2009 who received dental care under SDS. Ethics approval for this study was given by the institutional review board (IRB, Ref Code: N-18-068). Informed consent for the use of dental records for research was previously obtained from students’ parents.

All available dental records from 2009 (baseline examination in Primary 1) to 2017 (final follow-up under SDS in Secondary 3) were extracted from the Integrated Dental Electronic Assessment System (IDEAS) adopted by SDS and anonymised. Each dental record comprised the oral health findings and treatment rendered in a single dental visit, documented contemporaneously by the clinician (either a dentist or dental therapist; both trained, qualified, and registered with Singapore Dental Council) who provided care. Oral health examinations were conducted on each student using a mouth mirror and a dental probe, under lighting on a dental chair. Visuo-tactile detection for the presence of cavitated carious lesions was carried out on 5 surfaces (mesial, distal, lingual/palatal, labial/buccal, and incisal/occlusal) of each erupted tooth. Overall oral hygiene status was assessed and classified into 4 categories (good, fair, poor, and very poor) based on the presence of plaque, debris, and calculus intraorally. The presence of tooth hypoplasia was also recorded clinically through visual assessment based on the presence of deficient enamel in furrows, bands, and pits, which may be localised or generalised. Examinations were conducted either in mobile dental clinics, field dental clinics sited within the school compound, or at a centralized referral centre.

General health indicators examined include self-reported medical history and drug allergies. Sociodemographic data, including gender, age, race, and residence type, were also retrieved. Residence type was used as a proxy to SES, and classified into 3 ordinal groups. Besides individual-level SES measures, school-level measures were also recorded. Schools were categorised into geographical regions based on Urban Redevelopment Authority (Singapore) planning areas.

According to the classifications by the Ministry of Education
Singapore, primary schools were categorized into 3 distinct types—Special Assistance Plan (SAP) schools committed to nurturing bilingual and bicultural students, non-SAP government schools, and others (including madrasah schools, special education schools, and home schooling). Secondary schools were categorised into 4 distinct types—autonomous, independent, nonautonomous government, and others.

Statistical analyses were carried out using Stata software (StataCorp LP, Stata Statistical Software: Release 14). The caries outcome was restricted to the permanent dentition, whereas caries in primary teeth was only included as 1 of the independent variables. Pre-post analysis was carried out by tabulating the within-individual DMFT change between years 2009 (baseline examination) and 2017 (final follow-up in SDS). Given that there were no negative changes in DMFT, caries increment was calculated by the absolute difference, rather than crude or net caries increments. Students were dichotomized into 2 groups based on DMFT change over the whole study period (2009 to 2017): no caries incidence (\( \Delta \text{DMFT} = 0 \)) and caries incidence (\( \Delta \text{DMFT} > 0 \)). To model the risk factors for caries incidence, sociodemographic characteristics, general health status, presence of any tooth hypoplasia, baseline dmft, baseline DMFT, and baseline oral hygiene status were analysed via univariate analysis. Variables with a \( P \) value that met the cutoff of 0.25 in the univariate analysis\(^{22} \) were assessed for suitability of inclusion in a multiple logistic regression model via an iterative process of exploratory association analysis. A cross-product interaction term between baseline DMFT and dmft status was included to test for multicollinearity analysis. A total of 728 students had missing values for risk factors, met a significance level of \( P < 0.05 \) or improved model fit (pseudo R\(^2 \)) were considered for inclusion. Likelihood ratio tests, Akaike information criteria (AIC), and Bayesian information criteria (BIC) values were used to determine the significance of each additional covariate. Forward stepwise and backward stepwise analyses were done to confirm the model. Fit of the model was assessed by the Hosmer-Lemeshow goodness-of-fit test, and regression diagnostics was performed. All statistical tests were 2-sided, and odds ratios with associated 95% CIs were reported. As the rare disease assumption was not met, relative risk regression was also carried out using a Poisson regression model with robust error variance\(^{24} \) to determine effect sizes in terms of risk ratios.

### Results

Records for a total of 42,753 students were retrieved. After excluding students with missing DMFT counts in either year (2009 or 2017), dental records for 30,349 students were analysed. A total of 728 students had missing values for risk factors under study. Thus, the final analysis was based on a sample of 29,617 individuals. The sociodemographic characteristics and baseline (oral) health status of the students are listed in Table 1.

Approximately two-thirds (66.1%) of the cohort remained caries-free in the permanent dentition (\( \text{DMFT} = 0 \)) throughout the schooling years. A small proportion (2.2%) had caries at baseline (\( \text{DMFT} > 0 \)) but did not develop any new caries during their school years (\( \Delta \text{DMFT} = 0 \)). Of the 9389 (31.7%) students who had caries incidence in the permanent dentition (\( \Delta \text{DMFT} > 0 \)), 48.2% had a DMFT increment of 1; 26.0% had a DMFT increment of 2, and 25.8% had a DMFT increment of 3 or more. The overall mean caries increment (\( \Delta \text{DMFT} \)) was 0.67 (95% CI: 0.66-0.69). Based on the univariate analysis (Table 2), the relative risk of having caries incidence in the permanent dentition was higher when caries was present in the primary dentition (ie, the dmft count was 1 or more at baseline) compared to no baseline caries in the primary dentition. The adjusted risk ratio (Adj. RR) was 1.88 (95% CI: 1.81-1.95) (Table 3).

The female gender was associated with higher risk of caries incidence compared to the male gender (Adj. RR: 1.23; 95% CI: 1.19-1.27). Chinese ethnicity was associated with a higher risk of caries incidence compared to Indian ethnicity (Adj. RR: 1.10; 95% CI: 1.04-1.17). No statistically significant difference in the risk of caries incidence was observed for Malay and other ethnicities as compared to Indian ethnicity. The mean age (in years) in Primary 1 was found to differ between

| Characteristic            | Mean (SD) |
|---------------------------|-----------|
| Age in 2009               | 7.02 (0.18) |
| Gender (Male)             | 15,049 (50.8) |
| Race                      |           |
| Chinese                   | 20,294 (68.5) |
| Malay                     | 3675 (12.4) |
| Indian                    | 2820 (9.5) |
| Others                    | 2828 (9.6) |
| Primary School Region     |           |
| Central                   | 7421 (25.1) |
| East                      | 4800 (16.2) |
| North                     | 4590 (15.5) |
| North-East                | 5933 (20.0) |
| West                      | 6873 (23.2) |
| Primary School Type       |           |
| Public                    | 26,354 (89.0) |
| SAP                       | 3241 (10.9) |
| Others                    | 22 (0.1) |
| Secondary School Type     |           |
| Public                    | 21,403 (72.3) |
| Autonomous                | 5460 (18.4) |
| Independent               | 2332 (7.9) |
| Others                    | 422 (1.4) |
| Housing Type              |           |
| Private                   | 5055 (17.1) |
| 1-3 room HDB              | 4349 (14.7) |
| 4-5 room HDB              | 20,213 (68.3) |
| Baseline dmft ≥ 1         | 15,090 (51.0) |
| Baseline DMFT ≥ 1         | 1602 (5.4) |
| Hypoplasia                | 994 (3.4) |
| Existing Medical Condition| 5587 (18.9) |
| Drug Allergy              | 872 (2.9) |
| Baseline Oral Hygiene Status|         |
| Good - Fair               | 25,062 (84.6) |
| Poor - Very Poor          | 4555 (15.4) |

\( \text{DMFT} = \) decayed, missing, or filled teeth; \( \text{HDB} = \) Housing Development Board; \( \text{SAP} = \) special assistance plan; \( \text{SD} = \) standard deviation.
individuals with and without caries incidence (7.03 vs 7.01; \(P<.001\)), but no statistically significant association between age and caries incidence in the permanent dentition was found after adjustment for other covariates.

Education enrolment in nonmainstream primary school types ("Others") including Special Educational Needs (SPED), Madrasah schools, and home schooling was associated with higher risks of caries incidence (Adj. RR 1.94; 95% CI: 1.38-2.73), compared to public schools. The geographical location of primary schools was also associated with DMFT increment, with a higher risk of caries incidence in the East (Adj. RR: 1.21; 95% CI: 1.15-1.28) and West (Adj. RR: 1.13; 95% CI: 1.08-1.19), as compared to the Central region. By residence type, the risk of caries incidence was higher among those living in 1-2

### Table 2 – Univariate analysis of potential risk factors of caries incidence.

| Variable* | No caries incidence (DMFT = 0), N = 20,228 | Caries incidence (DMFT > 0), N = 9389 | Odds ratio (95% CI) | P value | Risk ratio (95% CI) | P value |
|-----------|------------------------------------------|--------------------------------------|---------------------|---------|---------------------|---------|
| Age in 2009 | 7.01 (7.01-7.02) | 7.03 (7.02-7.03) | 1.40 (1.23-1.59) | <.001 | 1.23 (1.14-1.32) | <.001 |
| Gender | | | | | | |
| Male | 10,751 (71.4%) | 4298 (28.6%) | 1.00 | | | |
| Female | 9477 (65.1%) | 5091 (34.9%) | 1.34 (1.28-1.41) | <.001 | 1.22 (1.18-1.27) | <.001 |
| Race | | | | | | |
| Indian | 2040 (72.3%) | 780 (27.7%) | 1.00 | | | |
| Chinese | 13,763 (67.8%) | 6531 (32.2%) | 1.24 (1.14-1.35) | <.001 | 1.16 (1.09-1.24) | <.001 |
| Malay | 2501 (68.1%) | 1174 (31.9%) | 1.23 (1.10-1.37) | <.001 | 1.15 (1.07-1.25) | <.001 |
| Others | 1924 (68.0%) | 904 (32.0%) | 1.23 (1.10-1.38) | <.001 | 1.16 (1.07-1.25) | <.001 |
| Residence Type | | | | | | |
| Private | 3583 (70.9%) | 1472 (29.1%) | 1.00 | | | |
| HDB 1-3 room | 2857 (65.7%) | 1492 (34.3%) | 1.27 (1.17-1.39) | <.001 | 1.18 (1.11-1.25) | <.001 |
| HDB 4-5 room | 13,788 (68.2%) | 6425 (31.8%) | 1.13 (1.06-1.21) | <.001 | 1.09 (1.04-1.14) | <.001 |
| Primary school region | | | | | | |
| Central | 5254 (70.8%) | 2167 (29.2%) | 1.00 | | | |
| East | 3085 (64.3%) | 1715 (35.7%) | 1.35 (1.25-1.46) | <.001 | 1.22 (1.16-1.29) | <.001 |
| North | 3181 (69.3%) | 1409 (30.7%) | 1.07 (0.99-1.16) | .081 | 1.05 (0.99-1.11) | .081 |
| North East | 4191 (70.6%) | 1742 (29.4%) | 1.01 (0.93-1.09) | .840 | 1.01 (0.95-1.06) | .840 |
| West | 4517 (65.7%) | 2356 (34.3%) | 1.26 (1.18-1.36) | <.001 | 1.17 (1.12-1.23) | <.001 |
| Primary school type | | | | | | |
| Government | 17,975 (68.2%) | 8379 (31.8%) | 1.00 | | | |
| SAP | 2245 (69.3%) | 996 (30.7%) | 0.95 (0.88-1.03) | .220 | 0.97 (0.92-1.02) | .223 |
| Others | 8 (36.4%) | 14 (63.6%) | 3.75 (1.57-8.95) | <.001 | 2.00 (1.46-2.75) | <.001 |
| Secondary school type | | | | | | |
| Government | 14,469 (67.6%) | 6934 (32.4%) | 1.00 | | | |
| Autonomous | 3797 (69.5%) | 1663 (30.5%) | 0.91 (0.86-0.97) | .006 | 0.94 (0.90-0.98) | .007 |
| Independent | 1691 (72.5%) | 641 (27.5%) | 0.79 (0.72-0.87) | <.001 | 0.85 (0.79-0.91) | <.001 |
| Others | 271 (64.2%) | 151 (35.8%) | 1.16 (0.95-1.42) | .142 | 1.10 (0.97-1.26) | .132 |
| Existing medical condition | | | | | | |
| No | 16,364 (68.1%) | 7666 (31.9%) | 1.00 | | | |
| Yes | 3864 (69.2%) | 1723 (30.8%) | 0.95 (0.89-1.01) | .124 | 0.97 (0.93-1.01) | .126 |
| Drug allergy | | | | | | |
| No | 19,633 (68.3%) | 9112 (31.7%) | 1.00 | | | |
| Yes | 595 (68.2%) | 277 (31.8%) | 1.00 (0.87-1.16) | .967 | 1.00 (0.91-1.11) | .967 |
| Baseline dmft | | | | | | |
| 0 | 11,448 (78.8%) | 3079 (21.2%) | 1.00 | | | |
| ≥1 | 8,780 (58.2%) | 6310 (41.8%) | 2.67 (2.54-2.81) | <.001 | 1.97 (1.90-2.05) | <.001 |
| Baseline DMFT | | | | | | |
| 0 | 19,573 (69.9%) | 8442 (30.1%) | 1.00 | | | |
| ≥1 | 655 (40.9%) | 947 (59.1%) | 3.35 (3.02-3.72) | <.001 | 1.96 (1.88-2.05) | <.001 |
| Baseline oral hygiene | | | | | | |
| Good/Fair | 17,399 (69.4%) | 7663 (30.6%) | 1.00 | | | |
| Poor/Very Poor | 2829 (62.1%) | 1726 (37.9%) | 1.39 (1.30-1.48) | <.001 | 1.24 (1.19-1.29) | <.001 |
| Tooth hypoplasia | | | | | | |
| No | 19,775 (69.1%) | 8848 (30.9%) | 1.00 | | | |
| Yes | 453 (65.6%) | 541 (34.4%) | 2.67 (2.35-3.03) | <.001 | 1.76 (1.66-1.87) | <.001 |

CI = confidence interval; DMFT = decayed, missing, or filled teeth; HDB = Housing Development Board; SAP = special assistance plan; SD = standard deviation.

* Mean (SD) for age; for all other variables: N (%).

† Results of log-binomial and modified Poisson (Poisson regression with robust error variance) produced the same estimates.

‡ Postestimation test of parameters.

§ HDB 1-3 Room includes Welfare Homes, Factory Quarters, HDB 1-3 room Flats; HDB 4-5 room includes HDB 4-5 room/HUDC/Executive Flats.
Room (Adj. RR: 1.13; 95% CI: 1.07-1.20) and 4-5 room flats (Adj. RR: 1.06; 95% CI: 1.01-1.11) in public housing, as compared to those living in private residences.

Poor or very poor oral hygiene at baseline was associated with higher risks of caries incidence (Adj. RR 1.07; 95% CI: 1.03-1.12) compared to good or fair oral hygiene. Presence of tooth hypoplasia was associated with higher caries risk, with reference to no hypoplasia (Adj. RR: 1.58; 95% CI: 1.49-1.68).

The Hosmer-Lemeshow goodness-of-fit test with 10 groups suggested that the logistic regression model was of an adequate fit for risk prediction ($\chi^2$ statistic = 14.51, $P = .069$). The area under the Receiver Operating Characteristic (ROC) curve was 0.67 (Figure). A total of 60.2% of students were correctly classified by DMFT increment status, with sensitivity (69.6%) and specificity (55.8%) at a predicted probability cutoff of 0.30 derived using the Youden Index method.  

Discussion

Data collected from developed countries have repeatedly shown a skewed caries distribution, with 80% of disease burden concentrated in 20% of selected populations of children.  In our study, 18.7% of students demonstrated 80% of all DMFT counts in 2017 (year of final follow-up), suggesting...
a similarly unequal distribution of disease burden even in the backdrop of a universal dental care programme. This underlines the necessity of identifying caries-prone individuals and groups for targeted intervention.

Our findings suggest that caries in the primary dentition is a key risk factor for caries incidence in the permanent dentition. Risk of caries incidence over 8 subsequent years among students with a baseline dmft score of 1 or more was 1.88 times that in students without caries in the primary dentition. This is in line with the findings of other longitudinal studies, including another 8-year cohort study in China, where children with caries in the primary dentition at 3-5 years were found to have relative risk of caries in the permanent dentition of 2.6. It is uncertain if caries development in both dentitions share the same pathway, as oral bacterial species were found to be different in primary and permanent dentitions. Nevertheless, the consistent association found between caries in the primary and permanent dentition implies that childhood caries serves as a useful indicator for delivering timely interventions to prevent caries in the later stages of life.

Caries experience in the permanent dentition at baseline was also associated with a higher risk of caries incidence in the permanent dentition. This is supported by caries risk-assessment models that include past caries as a predictor of future caries. Although a combination of the presence of caries in the primary and permanent dentitions at baseline was found to be associated with a higher odds for DMFT increment in the permanent dentition, no effect modification was found in our study, with the interaction term introducing multicollinearity. As with other studies, tooth enamel defects in the form of tooth hypoplasia, which increases acid solubility and enables bacteria adhesion, was a noted caries risk factor in our sample.

Studies have shown that dental caries is clustered in children from families with low SES. Based on principal component analysis, a study in Sweden showed that larger SES models better explained caries prevalence than models using a smaller number of SES indicators, with stronger associations between SES and caries in the primary versus the permanent dentition. However, only housing type was available in the SDS system and, thus, was adopted as a proxy for SES in our study. In the Singapore context, housing type has been found to be positively associated with household income and is considered a reasonable proxy for SES, given the significant difference in prices of different types of housing. Despite the use of a single SES indicator, our study findings suggest an association between lower SES and caries incidence, with a gradual increase in caries risk in the following order: residence in private housing, residence in 4- to 5-room public housing, residence in 1- to 3-room public housing. In addition to individual-level SES, school-level measures, namely geographical district and school type, have been incorporated in this study to profile the variation in caries burdens across different population subgroups. The mechanisms of the association between SES and dental caries include larger predisposing factors, such as the lack of economic means and empowerment to engage in healthy lifestyles (eg, diets low in sugar and good oral hygiene practice). Collectively, these indicators have implications for caries control and allocation of resources in the local population.

In terms of demographic characteristics, the female gender was associated with higher risks of caries development. This is supported by findings among children in United States but not South Asia. Explanations for a higher caries rate among females include biological factors such as variants of the X-linked Amelogenin gene, lower salivary flow rate, earlier tooth eruption, and frequent snacking habits. Other studies that found lower DMFT counts in females than in males speculated that a cultural emphasis on aesthetics in girls may play a part in improving their oral health. Our finding of a lower risk ratio for caries incidence among Indians, as compared to Chinese, is consistent with a cross-sectional study among South Asians. It is unclear if dietary differences such as a vegetarian diet among some Indians or variations in oral hygiene practices between races account for the finding. Nonetheless, while the Malay race appeared to be a predictor of caries incidence in the primary dentition among preschoolers in Singapore, this was not found to be the case in the permanent dentition among school-going children in our study after adjusting for covariates.

Our study also showed that students from nonmainstream schools have a higher risk of caries incidence than those in public schools. The high caries risk among students in special education schools is in line with findings of prior studies demonstrating a higher dental caries prevalence among children with special needs. However, the estimates should be interpreted with caution due to the small sample size and potential for selection bias, with more cooperative, more dentally aware, or students with more dental problems seeking care at SDS in this group. Students enrolled in schools in the East and West regions have higher risks of caries incidence compared to students enrolled in the Central region. A separate univariate analysis indicated a higher proportion of students with caries in the permanent dentition at baseline in the East and West as well. This suggests the presence of explanatory factors extrinsic to the SDS, such as possible regional differences in oral health awareness of students or parents and water fluoridation levels, which can be explored in the future.

The model fit and predictive values were moderate. This suggests that there may be other predictors of caries incidence that are not captured in the SDS database, such as oral health behaviours (diet and toothbrushing habits) and salivary or microbiological factors. A limitation of this study was that the clinicians were not calibrated, and dental radiographs were not routinely taken, given the nature of the nationwide SDS. Nevertheless, misclassification of the presence of dental caries is likely to be nondifferential, given the large number of students and clinicians, and multiple examinations per student by different clinicians over the schooling years. The caries outcome was set at cavitation level. Clinical records of white spot lesions were not available before enhancements to the electronic system in 2012 and, thus, were not included in the analysis. As students in our target population are usually in the mixed dentition phase, the number of erupted permanent teeth at risk of dental caries may differ across individuals and could not be adjusted due to the lack of data. Nevertheless, since all students belonged...
to the same cohort (Primary 1 in 2009), the variation in their age and number of erupted permanent teeth is expected to be small. The strength of this study is the large sample size, which allows for sufficient statistical power to detect the differences across groups. This is also the first study using the 8-year longitudinal data from the nationwide SDS in Singapore, which is representative of the oral health status of the population.

Conclusions

This study showed the unequal distribution of caries burden even among children and adolescents in a structured school dental service programme. Caries incidence in permanent dentition during adolescence is associated with childhood factors, including clinical status (tooth hypoplasia, the presence of dental caries in the primary and permanent dentition, and poor oral hygiene) and sociodemographic characteristics (female gender, ethnicity, lower SES, and enrolment in non-mainstream schools or primary schools in the East and West regions of Singapore). Beyond enhancing risk classifications for long-term oral health outcomes, these findings can aid in the structuring of dental service provision and the delivery of targeted interventions to at-risk children and adolescents.

Conflict of interest

None disclosed.

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