Identifying high-risk children for dental caries in school settings: A simple predictive model

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(Index words: dental caries, risk prediction, model development, model validation)

Abstract

Background: Untreated caries in permanent teeth is the most prevalent condition worldwide. Use of a simple, validated caries risk prediction tool will offer a low-cost mechanism to identify high-risk children for targeted preventive programmes.

Objectives: To develop and validate a caries risk prediction model for 5-6-year-old Sri Lankan children.

Methods: Two case-control studies were done for model development and validation. Cases and controls were defined as 8-9-year-olds with and without permanent tooth caries respectively. Based on dental records and confirmation by clinical examination, 120 cases and 360 controls for model development, and 100 cases and 100 controls for model validation were selected. Data was collected using dental records and a pretested parental self-administered questionnaire. Risk predictors were identified by logistic regression analysis. Cut-off point was determined by plotting a ROC curve.

Results: Four risk predictors were identified: ‘having 5 or more posterior decayed teeth’ (OR= 2.1, 95% CI:1.0- 4.4), ‘brushing frequency of once or less’ (OR= 3.5, 95% CI: 2.1-6.0), ‘not using fluoridated toothpaste’ (OR= 3.2, 95% CI:1.8-5.6) and ‘consuming more than two snacks containing fermentable carbohydrates in between meals’ (OR=1.6, 95% CI:0.9-2.9). A 10-point score was developed. Following external validation, a sensitivity of 31% (95% CI: 22.1%-41.0%) and a specificity of 87% (95% CI: 78.8% - 92.9%) was obtained for a cut-off value of 2.5.

Conclusion: The model could be used to identify high-risk children, especially in areas with higher disease burdens.

Introduction

Dental caries is a multifaceted public health challenge due to its high prevalence, incidence, negative impact on quality of life and huge economic cost. Untreated caries in permanent teeth is the most prevalent condition and untreated caries in primary teeth the 10th most prevalent condition globally [1].

Over the years a decline in prevalence and severity, and an increasingly skewed distribution of caries in children is seen [2], giving rise to polarization of dental caries among child populations [3]. Consequently, countries have adopted numerous caries risk assessment systems [4,5,6] for caries management. Such systems enable risk-based patient categorization and identification of high-risk individuals. It is often coupled with caries management protocols aimed at prevention of future caries such as SIGN guidelines, 2014 and Caries Management by Risk Assessment (CAMBRA), 2011. These protocols provide different combinations of evidence-based preventive strategies for managing the disease for different risk categories.

Caries risk assessment and prediction are risky concepts, with limited scientific evidence on effectiveness and validity for standardized caries risk assessment models [7]. Yet, they serve as valuable resources in dental education, facilitate communication with patients and their families, serve as guides for development of public health programmes and allocation of resources among vulnerable segments of the population [8]. It is cost-effective and economically beneficial to patients and oral health care systems, as costly advanced dental treatments could be avoided. Cost savings of preventive measures are shown to be most effective for children with the highest risk of caries [9].

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Caries risk prediction models in developed countries use advanced technologies such as microbiological tests, radiographic techniques, salivary analysis, and other laboratory tests, achieving higher levels of sensitivity, specificity and predictive values. However, they are more suitable to be used by dental professionals in clinical settings.

In Sri Lanka, cost-effective health interventions at field level have uplifted the health status of the public. One such intervention is provision of oral health services for children by School Dental Services provided by School Dental Therapists (SDTT). School Dental Services is an island-wide service yet, it is faced with service provision challenges due to insufficient workforce and poor access in remote areas. Although state-funded preventive interventions such as fissure sealants and fluoride applications are already initiated through School Dental Services, the fullest potential of such programmes is yet to grasp. SDTT do the first compulsory oral screening when the child is 5-6-years in grade 1. Periodic reviewing and recording of child's oral health status and related habits are done in grades 1, 4 and 7. The 3-year gap between oral screenings is too long for management of high-risk children. Sri Lankan data shows around 10% of children when screened in grade 4, to be having permanent tooth caries, within 2-3 years of permanent tooth eruption [10]. Recorded data on caries risk indicators of students are maintained by SDTT and, are used for monitoring the caries risk of the student. Availability of this secondary data could be retrospectively used for developing a caries risk prediction model.

A reducing trend in prevalence and severity of caries [11] together with a skewed distribution is seen among Sri Lankan children, where most disease burden is carried by a small proportion of children. High-risk children should be targeted for intense prevention through risk prediction. Therefore, the aim of this study is to develop and validate a caries risk prediction model to identify 'high-risk' children at the crucial age of 5-6-years during the first compulsory screening, just before eruption of permanent teeth to effectively implement preventive strategies within the School Dental Services in Sri Lanka.

Material and methods

The study population consisted of grade 4 students. Students with and without Decayed, Missing due to caries, and Filled Teeth (DMFT) in the permanent molars were defined as cases and controls respectively. Selection of cases and controls were based on dental recordings as at grade 4, and subsequent confirmation by clinical examination by a trained and calibrated dental surgeon under natural light using dental mouth mirrors while the child is seated on a normal chair. Blunt probes were used to remove any debris for better visualization of caries. Students with contradictory recordings were excluded.

Model development

A case-control study with 120 cases and 360 controls was done in Gampaha and Kalutara districts. Sample size calculation was done using OpenEpi software. Two-sided confidence level of 95, power of 80%, a case-to-control ratio of 1:3, and least extreme odds ratio to be detected of 2 was taken for the calculation. Hypothetical proportion of controls with exposure was taken as 55%, as approximately 55% did not get caries in permanent teeth despite having carious deciduous teeth [12]. Design effect of 1.2 and 2% allowance for non-response were taken.

A computer-based standardized data abstraction form was used to abstract data from dental records. A pre-tested parental self-administered questionnaire was also used to complement data on dental records. A preliminary study which identified factors associated with dental caries among 5-6-year-olds aided the development of the parental questionnaire.

A trained data abstractor blinded to the hypothesis and objectives of the study entered data into the computer-based form, which was imported into a Statistical Package for Social Sciences-version 20 spreadsheet. After merging the two data sets collected through parental questionnaires and dental records, data were analysed in 2 stages.

a. Determination of predictors for caries in permanent molars

Bivariate analysis was carried out to test the association between potential risk predictors and dental caries. Significance testing was done using chi-squared test. P value was taken as 0.2.

b. Logistic regression analysis for development of risk scores

Variables with a significance level of <0.2 were included in the initial model. Cell counts of less than 10 cases for independent variables were excluded from analysis as a minimum sample size of 10 cases for each independent variable has been suggested [13]. Backward logistic regression was performed where variables were entered into the model at 0.05 and removed at 0.1 significance levels. The best model which predicted dental caries in permanent teeth was selected. Goodness of fit was assessed and overall % correctly identified was determined. The Omnibus test, Cox and Snell Square test, Negelkerke R Square test, Hosmer and Lameshow tests and Wald statistics test were also performed.

Handling of missing data: Missing values of dental records were replaced using data on similar variables in the parental questionnaire.

Model validation

A case-control study was done in Colombo district, to assess the predictive validity through external validation of the developed model and to determine a cut-off point for the risk score. Sample size of 100 cases and 100 control were taken, as it is recommended as the minimum sample size required for model validation to have reasonable power [14]. Similar selection criteria, case definitions, sampling technique and data abstraction as those used for model development were applied. A pretested parental self-administered questionnaire on identified predictors was used to compensate for missing values.

For each case and non-case, a risk score was calculated by summation of assigned values for each predictor. Standard receiver operating characteristic (ROC) was plotted.

To decide on the optimal threshold that gives maximum correct classification d^2 was calculated. The distance between the point (0, 1) and any point on the curve is d^2. d^2 was calculated for each observed cut-off point, using the below-mentioned formula.

$$d^2 = (1\text{-sensitivity})^2 + (1\text{-specificity})^2$$

The point where the distance is minimal was located, which is the optimal cut-off point. Sensitivity, specificity and area under the curve were determined.

Ethical clearance was obtained from the Ethics Review Committee, Faculty of Medicine, University of Colombo. Permission to carry out the study was obtained from Ministry of Health and Ministry of Education. Informed written parental consent was obtained for all participants.

Results

The response rate which was similar for cases and controls for the parental self-administered questionnaire was 66.25 %. Missing data were excluded from the initial analysis. Table 1 illustrates the significant risk factors at 0.2 level of significance. The sample sizes differ due to differences in response rates to each question.

Table 1. Significant risk factors for developing caries in permanent molar teeth via bivariate analyses in comparison with controls (level of significance = 0.2)

	Variable	*OR*	*Significance*	*N*
1	Sex	1.7	$p = 0.015$	480
2	Having 5 or more posterior decayed teeth[#]	3.4	$p < 0.001$	456
3	Having a posterior dmft index of 5 or more[#]	2.8	$p < 0.001$	458
4	Not brushing in the morning[#]	7.3	$p < 0.001$	408
5	Not brushing after dinner[#]	3.6	$p < 0.001$	407
6	Having a total frequency of brushing of 1 or less[#]	3.6	$p < 0.001$	407
7	Not using fluoridated toothpaste[##]	2.3	$p = 0.009$	250
8	Having three or more extracted teeth of mother[##]	1.8	$p = 0.038$	288
9	Having three or more filled teeth in mother[##]	2.3	$p = 0.039$	278
10	Father's educational status[##]	2.5	$p < 0.001$	318
11	Mother's occupational status[##]	1.9	$p = 0.030$	283
12	Father's occupational category[##]	2.6	$p = 0.007$	202
13	Mother's educational status[##]	1.6	$p = 0.061$	317
14	Having toffee/ chocolate/ other sweets several times a day[##]	1.5	$p = 0.118$	300
15	Sugar consumption of more than 2 snacks[#] : grade 1	1.4	$p = 0.203$	395
16	Mobile phone[##]	1.7	$p = 0.092$	305

[#] Secondary data recorded when student was in grade 1

[##] Primary data from parental questionnaire collected when same student is in grade 4

Missing values were replaced by combining variables. Some variables were omitted due to an increased percentage of missing values. Table 2 illustrates new variables created after replacing missing values.

Table 2. Variables before and after missing value replacement

	Variable	*Description*	*New variable*
1	Having 5 or more posterior decayed teeth	Missing values replaced with other records maintained by SDT	Having 5 or more posterior decayed teeth
2	Having a posterior dmft index of 5 or more	Taken as it is, as no other records available for replacing missing values	Having a posterior dmft index of 5 or more
3	Not using fluoridated toothpaste	Missing values replaced using both records and questionnaires	Not using fluoridated toothpaste
4	Not brushing in the morning	Combined after replacing missing values using records and questionnaires	Having a total frequency of brushing of 1 or less
5	Not brushing after dinner		
6	Having a total frequency of brushing of 1 or less		
7	Having toffee/ chocolate/ other sweets several times a day	Combined after replacing missing values using records and questionnaires	Sugar consumption of more than 2 snacks
8	Sugar consumption of more than 2 snacks		
9	Having three or more extracted teeth of mother		
10	Having three or more filled teeth in mother	Omitted due to increase % of missing values	
11	Father's educational status		
12	Mother's occupational status		
13	Father's occupational category		
14	Mother's educational status		
15	Mobile phone		
16	Sex	Omitted as model to be applied also in unisex schools	

Odds ratios of new variables created after replacement of missing values at the bivariate level with caries risk were: 3.9 for 'Having 5 or more posterior decayed teeth' (n=473); 2.8 for 'Having a posterior dmft index of 5 or more' (n=458); 4.3 for 'Having a total frequency of brushing of 1 or less' (n=462); 3.9 for 'Not using fluoridated toothpaste' (n=358) and 3.2 for 'Sugar consumption of more than 2 snacks' (n=467) all of which the significance was zero. Table 3 illustrates the output of logistic regression analysis.

Table 3. Logistic regression predicting likelihood of having caries on permanent teeth of 5-year-olds, by the time student goes to grade 4 (after replacing missing values)

Predictor variable	*B*	*SE (β)*	*Wald*	*Df*	*P*	*Exp (β)*	*95% CI for Exp (β)*	
							Lower	*Upper*
Having 5 or more posterior decayed teeth	0.7	0.4	4.0	1	0.045	2.1	1.0	4.4
Having a total frequency of brushing of 1 or less	1.3	0.3	21.5	1	0.000	3.5	2.1	6.0
Not using fluoridated toothpaste	1.2	0.3	16.5	1	0.000	3.2	1.8	5.6
Sugar consumption of more than 2 snacks	0.5	0.3	2.6	1	0.105	1.6	0.9	2.9
Nagelkerke R^2	22.4%; Cox and Snell R^2 15.9							
Hosmer and Lemeshow test	p=0.120							
Classification accuracy	75.1%							

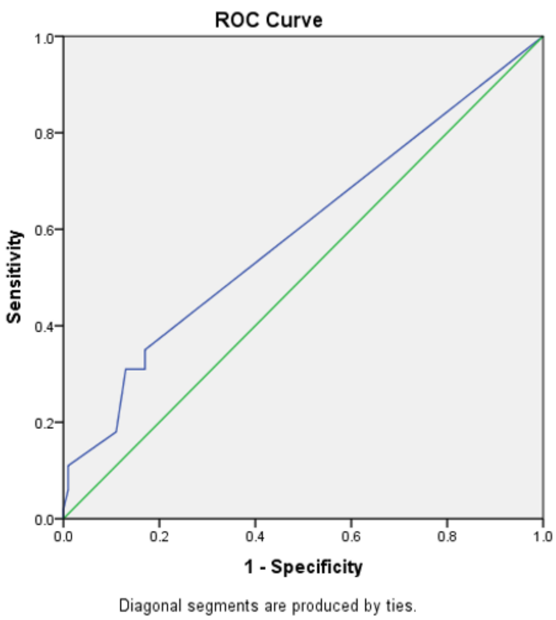
Model validation

For ease of application 0.5 rounding of adjusted odds ratios were taken as the final risk prediction model. Predictor variables and the assigned scores are shown in Table 4.

Table 4. Predictor variables included in the caries risk prediction model for 5-6-year-olds

Predictor variable	*Categories*	*Score*
Having 5 or more posterior decayed teeth	No	0
	Yes	2
Having a total frequency of brushing of 1 or less	No	0
	Yes	3.5
Not using fluoridated toothpaste	No	0
	Yes	3
Sugar consumption of more than 2 snacks	No	0
	Yes	1.5
Total		**10**

ROC curve plotted for validation sample using the scores is shown in Figure 1.



Cut-off value	*Sensitivity*	*1-Specificity*	*Distance from curve (d^2)*
-1	1	1	1
0.75	0.35	0.17	0.4514
1.75	0.31	0.17	0.505
2.50	**0.31**	**0.13**	**0.493**
3.25	0.18	0.11	0.6845
4.00	0.11	0.01	0.7922
4.75	0.10	0.01	0.8101
5.25	0.08	0.01	0.8465
6.00	0.06	0.01	0.8837
8.25	0.01	0.00	0.9801
11.00	0.00	0.00	1

Figure 1. **ROC curves for summary risk scores against the presence of caries on permanent molars among the validation sample with odds ratios rounded to nearest 0.5.**

The area under the curve was 0.592 (95% CI: 0.514-0.671). Thus, around 60% of the variability is explained by the risk score. Sensitivity of 31% (95% CI: 22.1% - 41.0 %) and specificity of 87% (95% CI: 78.8%-92.9 %) was observed.

Discussion

Our approach was to build a simple and user-friendly model to predict the risk for developing caries in permanent molars by the time children are in grade 4, to be administered to children aged 5-6-years. Permanent molars are the most caries-prone teeth [15]. The model could be administered during first screening of school children in grade 1 by which time the first permanent molars are about to erupt in majority of children [16]. It could be used as a screening tool to identify high-risk children, in school settings by SDTT or at clinic settings by oral health professionals. With three simple interviewer-administered questions and one clinical examination finding, the tool is inexpensive and could be administered quickly with minimal discomfort to the child. Suitability to the local setting, simplicity where reliable data could be collected from children even when parental engagement is minimal, possibility for using for health education and health promotion efforts at the individual and community level are advantages of the model. Although several other risk prediction models exist globally where salivary, radiological, and microbiological analysis is necessary, they are of limited use in school settings, particularly in lower-middle-income countries.

Multiple logistic regression analysis used to develop the current model, has been used in many studies to determine the extent to which predictors could differentiate between high and low caries risk categories [17]. All four risk predictors in the current model are supported by literature and are included in well-known risk-prediction models.

Studies have consistently shown children with high baseline caries levels on deciduous teeth to be more likely to develop future caries in their permanent teeth [18]. Past caries experience is quoted as the most powerful predictor of future caries [19, 20]. Caries on primary molars was the most powerful predictors of permanent caries [21].

Diet plays a pivotal role in the aetiology of dental caries [22]. However, it is challenging to assess dietary exposures accurately [23] and define ‘high’ and ‘low’ sugar consumption [24]. Snacking has become an important risk indicator for caries development in children [25,26]. CAMBRA model and American Academy of Paediatric Dentistry (AAPD CAT) also uses snacking frequency related predictors for caries risk assessment.

Supported by more than half a century of research, benefit of fluoridated toothpaste is firmly established [27]. It is used in CAMBRA, American Dental Association (ADA) Caries Risk Assessment, AAPD CAT and cariogram.

Despite the inconclusive evidence regarding oral hygiene status and caries [28, 29], in a Sri Lankan study among adolescents, oral hygiene status emerged as the most significant determinant of dental caries [30]. Toothbrushing related predictor in the current model is in line with the current recommendation of twice a day toothbrushing.

Therefore, all 4-predictor retained in the final risk prediction model related to baseline caries experience, brushing, fluoride toothpaste and diet have face validity and consensual validity. Some important variables not included are special health care needs, salivary flow, salivary buffering capacity and elevated mutans streptococci levels. Measuring salivary flow, salivary buffering capacity and elevated mutans streptococci levels is beyond the scope which could be performed in a school setting. Despite the risk level, children with special healthcare needs necessitates special attention.

The developed model explained between 15.9% to 22.4% of the variance in caries status. This is in line with a model developed through multivariate analysis which explained around 13% of caries variation among American preschool children [31]. A reason for the unexplained variance may be, absence of important predictors such as bacterial counts and salivary pH on which data collection was beyond the scope of the current study. As huge unexplained variations could lead to failure to produce accurate predictions [32], it is important to be cautious in application of the model. However, even moderately performing models to do better than clinicians' own assessments [33] and are useful depending on clinical judgement and context [34].

High specificity indicates children without a higher risk for caries are unlikely to be categorized as 'high risk' leading to unnecessarily overburdening services. Having a high specificity at the expense of low sensitivity is justified as School Dental Services carry out compulsory screenings periodically for all children. The combined sensitivity and specificity of 118 in current study, is in line with 'Cariogram' which ranged from 110 to 139 and it is the only system for which prospective studies have been conducted to assess validity [35].

For targeted management of caries, preventive strategies such as dietary modifications, use of fluorides (brushing, mouth washes, fluoride supplements, and professional topical treatment), use of xylitol, calcium phosphate, antimicrobials and fissure sealants are used in guidelines such as SIGN (2014), AAPD (2014) and CAMBRA (2011). Locally, 'Save molar programme' which is a special community oral health programme for protecting molar teeth of children is already persisting. The developed model could be used to select children for such programmes.

As caries shows polarization, the yield of the tool is increased by targeted screening of socioeconomically disadvantaged children linked with high sucrose consumption, low fluoride usage and poor access to oral health services who are at higher possibility of developing the disease. The model is useful in caries risk assessment and patient-centred caries management, as it includes modifiable risk factors. However, discretion of the service provider may be needed in identifying children with obvious higher future risk for caries such as medically compromised, if failed to be identified by the model.

Conclusion

The model is useful as a simple screening tool to identify children with a high-risk for caries, amenable to further improvements.

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Conflict of interests

There are no conflict of interests.

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