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Determinants of Early Childhood Caries and their interactions: A Structural Equation Modelling approach

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Objective: Early Childhood Caries (ECC) has been common among preschoolers in Sri Lanka over decades. A broad spectrum of determinants that act upon different levels is responsible for its development. Therefore, the relationships among these determinants should be studied extensively to control ECC. ***Design***: Descriptive cross-sectional study with multistage cluster sampling. ***Setting***: Registered preschools in Gampaha District. ***Participants***: A total of 1038 three to four-year-olds and their mothers. ***Main outcome measures***: Direct, indirect, and total effects of the determinants of ECC in structural equation models. ***Results***: Sweet consumption had direct effects from permissive parenting (β=0.26, p=0.00) and the sweet consumption behaviour of the family (β=0.17, p=0.01). Oral hygiene behaviours had direct effects from permissive parenting (β=-0.46, p=0.00) and maternal oral health related self-efficacy (β=0.23, p=0.00). The dental attendance pattern had total effects from knowledge (β=0.18, p=0.00) and permissive parenting (β=-0.16, p=0.00). ***Conclusions***: Parenting style, family sweet consumption behaviour and maternal oral health related self-efficacy were the most influential second-line determinants that affected oral health behaviours: sweet consumption, oral hygiene, and dental attendance pattern for the development of ECC.

Keywords*: dental caries, preschool children, structural equation modelling*

Introduction

Early Childhood Caries (ECC) is "the presence of one or more decayed (non-cavitated or cavitated lesions), missing (due to caries), or filled tooth surfaces in any primary tooth in a child 71 months of age or younger" (American Academy of Pediatric Dentistry, 2008). Dental caries in the deciduous dentition is the 12th most prevalent disease, affecting 560 million children worldwide (Kassebaum *et al*., 2017). ECC is prevalent among preschool children worldwide and is often untreated below three years (Tinanoff *et al*., 2019). In the 2015/2016 National Oral Health Survey (NOHS) in Sri Lanka, the prevalence of dental caries in the deciduous dentition was 63.1%, with a mean dmft of 3.0 (±3.5) in five-year-old children (Ministry of Healthcare and Nutrition, 2018). Furthermore, its prevalence has stagnated in the country over the years as a result of unsatisfactory sweet consumption pattern, poor dental service utilization among preshoolers, and mothers' attitudes towards the deciduous dentition (Malmessa, 2017; Nanayakkara, 2013; Udayamalee, 2013). A substantial amount of research has been conducted worldwide and found a vast array of aetiological factors for ECC (Kirthiga *et al*., 2019). Frequent exposure to fermentable carbohydrates, oral hygiene practices, cariogenic bacteria levels, and low utilization of dental services are common factors (Anil and Anand, 2017; Kirthiga *et al*., 2019; Kotha, 2022; Meyer and Enax, 2018). Sweet consumption patterns, oral hygiene practices, utilization of dental services (in terms of access to the nearest government clinic, last visit to a dental clinic, type of dental clinic last visited, and type of dental treatment received at the last visit), nutrition factors, socioeconomic and socio-demographic factors, mothers' perception of oral health, and parenting style have been studied in Sri Lanka (Baminy, 2018; Malmessa, 2017; Nanayakkara, 2013; Udayamalee, 2013). Although many determinants have been identified for ECC, the prevalence is still high because they act in different ways in a complex aetiology. Therefore, it is crucial to understand how these determinants act upon each other in developing the disease. Determinants of ECC have been described as proximal, intermediate, and distal in different conceptual frameworks. The proximal determinants of ECC, which are the direct causes, are well documented and include the frequent use of fermentable carbohydrates, poor oral hygiene, cariogenic bacteria, and low utilization of dental services. These causes are in turn influenced by various underlying second-line determinants, such as the family's social, economic, cultural, and psychological factors. Therefore, it is challenging to prevent ECC simply by tackling only proximal determinants, as they are interrelated and influenced by the underlying determinants. Consequently, it is crucial to identify the effects and inter-relationships among the underlying second-line determinants that influence the proximal determinants.

Several frameworks have been used to study factors related to ECC at different levels (Fisher-Owens *et al*., 2007; Peres *et al*., 2019; Seow, 2012; Solar and Irwin, 2010). Research in other countries has studied these interrelationships in the development of ECC (Duijster *et al*., 2014;

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Mousavi *et al*., 2017; Qin *et al*., 2019; Qiu *et al*., 2014; Zhang *et al*., 2020). Although some have been conducted in Sri Lanka, none have examined the inter-relationships in the development of ECC. As the determinants act in a multilevel web, it is challenging to quantify the relationships between them. Regression analysis does not consider causal chains or interrelationships between determinants so attenuates the effect of distal or intermediate determinants due to the impact of stronger proximal factors (Aleksejūnienė *et al*., 2009). Structural Equation Modeling (SEM) can be used to identify relationships in complex determinant networks as it quantifies the direct and indirect effects of one factor on another within the network.

This study was conducted in preschools in the Gampaha district where the prevalence of dental caries in five-year-old children was 64%. This was similar to the national prevalence of dental caries in 5-year-old children (63%) in the latest NOHS (Ministry of Healthcare and Nutrition, 2018). The district also reflects the urban/rural mix of the country, with 84% of the population living in rural and 16% in urban, compared to 77% and 18% across Sri Lanka (Department of Census and Statistics, 2012). As the disease level and population structure in Gampaha are at par with the national level, the objective of this study was to assess the relationships and effects of determinants of ECC among 3-4-year-old preschoolers in the Gampaha district using SEM.

Methods

The Primary Investigator (PI) developed a conceptual framework on the determinants of ECC by referring to existing models (Fisher-Owens *et al*., 2007; Peres *et al*., 2019b; Seow, 2012; Solar and Irwin, 2010) and the findings of previous research on the determinants relevant to the local context. The conceptual framework was used to select the modifiable determinants to be analyzed in SEM, to develop an intervention targeting them. The proximal determinants were sweet consumption patterns, oral hygiene behaviours, and dental attendance. The second line determinants were oral health-related knowledge and attitudes, parenting style, maternal oral health-related self-efficacy, and the oral health-related behaviours of the family. A descriptive cross-sectional study of three to four-year-old preschool children of registered preschools in the Gampaha district and their mothers/caregivers was conducted over four-months in 2020. Preschoolers between their third and fifth birthdays on the day of data collection were selected.

The sample size was calculated using Lwanga and Lemeshow (1991). Each preschool was considered a cluster. The cluster size was taken as 15, based on previous literature, and the number of clusters was 72. The total sample was 1080 children. The number of variables included in the final structural model in the SEM would be 45. The rule of thumb for sample size varies from five to 20 items per variable (Schumacker and Lomax, 2010). Therefore, the maximum sample needed was, $45 \times 20 = 900$. Thus, the total sample would be adequate for the analysis. Multistage cluster sampling was used with probability proportionate to the size.

The data collection team was the two interviewers, the data recorder, and an assistant. The PI performed all the oral examinations and was trained and calibrated under a Consultant in Community Dentistry. The oral examination was carried out in a place with good natural daylight. Standardized sterilized dental instruments, which were Community Periodontal Index (CPI) probes and plane mouth mirrors were used for the oral examination procedure. ECC was recorded according to the criteria of WHO (2013) survey methods. Non-clinical data were collected with self-administered questionnaires and in interviews. The questionnaire enquired about sociodemographic data, maternal oral health-related knowledge, oral health-related attitudes, parenting style, and oral health-related self-efficacy. The interview enquired about child's sweet consumption pattern, oral hygiene, dental attendance and family oral health-related behaviours. Questions were formulated to cover several aspects of knowledge regarding ECC. Oral health-related attitudes were quantified using ten-items. The responses were assessed using a five-point Likert scale. The parenting style scale was determined using a local measure (Udayamalee, 2013), assessed on five point Likert scales. The self-efficacy scale for Maternal Oral care (SESMO) (Kakudate *et al.,* 2010) was adapted for local use using a modified Delphi technique (Hecht, 1979) using panel comprising a psychologist, a sociologist, two Community Dentists and two Restorative Dentists to extract the most important items. The responses were scored on a Likert scale. Questions on sweet consumption, oral hygiene, dental attendance and family oral health behaviours were developed from the literature. Child oral health behaviours included sweet consumption, oral hygiene and dental attendance. Family oral health behaviours included sweet consumption and oral hygiene patterns. Interviewers were trained to reduce interviewer bias. Questionnaires were pretested and piloted. Kappa coefficients of the test-retest reliability of the questionnaire and inter-interviewer reliability were 0.93 and 0.89 respectively.

Ethical clearance was obtained from the Ethics Review Committee of the Faculty of Medicine at the University of Colombo.

The data were analyzed using LISREL 9.0. First, measurement models were developed to analyze the relationships between the observed and latent variables in the sequence of model specification, model identification, model estimation, model testing, and model modification (Schumacker and Lomax, 2010). The measurement models were developed for all latent variables (sweet consumption, oral hygiene behaviour, dental attendance pattern, oral health-related knowledge, oral health-related attitudes, parenting style, maternal oral health-related self-efficacy, and oral health-related behaviours of the family) and modified until they achieved model fit. The knowledge indicators were knowledge regarding ECC, factors related to ECC, identification of ECC, and oral health behaviours responsible for ECC. The attitude indicators considered statements about "No need to worry about milk teeth as they exfoliate and a new set of teeth will erupt", "Decay of milk teeth does not affect my child", "A little child should be taken to a dental surgeon only when he/she complains of a tooth problem" and "Dental diseases are not serious problems as other diseases". Indicators considered in authoritative parenting style included "I explain to my child how I feel about his/her good habits

like brushing teeth twice daily", "I complement my child when he/she chooses fruits instead of sweet like biscuits and chocolate", "I explain to my child the importance of brushing teeth and reduction of having sweets frequently" and "I consider my child's preference when it comes to choose a snack". Indicators considered in authoritarian parenting included "When my child asks me why he/she has to brush twice a day, I tell him it is because, as parents, we do the best for you, therefore that you have to obey", "I have to shout at my child when I disapprove of his/her behaviours like not properly brushing teeth", "I tell my child that his /her teeth will be pulled out if he/she eats sweets frequently" and "I find myself struggling to change my child's sweet taking habits". Indicators considered in permissive parenting style were "I find it difficult to make the child brush at night", "I give in to my child when he/she causes commotions about sweets", "My child has to be given sweets like chocolate biscuits toffees every day" and I ignore my child's bad behaviour, like going to bed without brushing as he/she does not like to brush teeth at night". Indicators considered in maternal oral health efficacy were "I brush my child's teeth every day after dinner before going to bed however much he/she feels sleepy", "I finish brushing my child's teeth thoroughly even he/she dislikes it", "I encourage my child to eat a variety of homemade foods instead of short eats and snacks bought from shops", and "I continue to take my child for regular dental checkups even after the dental treatment was completed". Indicators considered in family sweet consumption were sweet and sweetened drinks consumption of the mother, sweet consumption of the father and sweet consumption of siblings. Indicators considered in child sweet consumption were frequency of consumption of biscuits/buns/cake, toffee/chocolate/chewing gums/Ice packets, milk packets/fruit juices/carbonated drinks and between meal/after main meal sweets. Indicators considered in the oral hygiene practices were type of ingredient used for toothbrushing, frequency of toothbrushing, supervised toothbrushing and brushing process of the child. Indicators of family oral hygiene behaviours were type of ingredient used for toothbrushing and frequency of toothbrushing. Indicators considered in child dental attendance were reasons for, duration of and treatment received at the last visit, and accessibility to the dental clinic. All data included in the measurement models were categorical. Therefore, a robust maximum-likelihood estimation method was used. Discriminant validity of the model was assessed using the correlation between the latent variables. After the measurement models were defined, a structural model was developed based on previous studies of determinants of ECC (Kumar *et al*., 2017; Qin *et al*., 2019; Qiu *et al*., 2014; Zhang *et al*., 2020). Models were modified by considering the significance of the pathways. The significance level of the $\boldsymbol{\beta}$ coefficient was set at 0.05. Because there were many free parameters in the final model, the model was over-identified. Goodness-of-fit indices used to assess the measurement and structural models included Satorra Bentler χ^2, RMSEA, GFI, AGFI, CFI, and SRMR.

Results

The final sample comprised 1038 children, with a non-response rate of 4%. Approximately 51% were girls and 90.8% were Sinhalese.

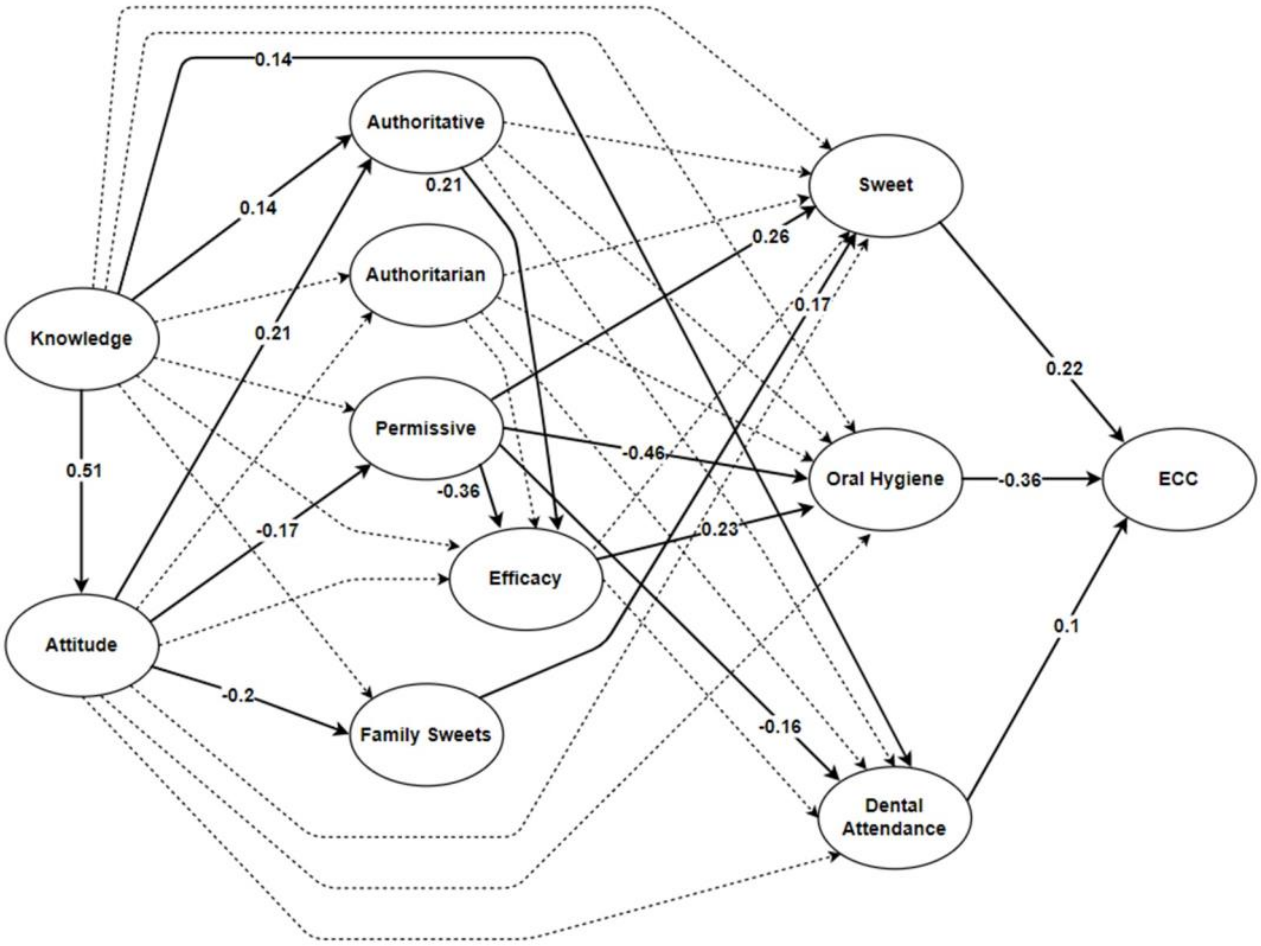
Table 1. Demographic characteristics of 1038 3–4-year-olds and their parents

		% (95% CI)
Gender of the child (n=1038)		
Girls		51.0 (48.1 - 54.0)
Boys		49.0 (46.0 - 52.1)
Ethnicity of the child (n=1038)		
Sinhala		90.8 (89.5 - 92.3)
Tamil		4.9 (4.0 - 6.4)
Muslim		3.9 (2.8 - 5.3)
Burgher		0.3 (0 - 1.0)
Residence (n=1036)*		
Permanent residents		89.4 (87.1 - 91.0)
Migrated within one year		10.6 (8.7 - 12.6)
Monthly family income (n=1030)*		
25,000 Rs		24.8 (21.9 - 27.3)
25,000 Rs-50,000 Rs		47.6 (45.4 - 50.3)
>50,000Rs		27.7 (24.7 - 30.2)
	Mother n=1033 % (95% CI)*	*Father n=1030* % (95% CI)*
Educational level		
No schooling	0.3 (0 - 1.0)	0.1 (0 - 1.0)
Grade 1 to 5	0.4 (0 - 1.0)	0.6 (0 - 1.0)
Grade 6 to 10	4.2 (3.3 - 5.5)	4.9 (3.6 - 6.3)
Up to GCE Ordinary Level	39.2 (36.2 - 42.2)	46.0 (42.9 - 49.1)
Up to GCE A Level	38.2 (35.2 - 41.2)	33.6 (31.0 - 36.5)
Diploma/vocational training	8.7 (7.0 - 11.1)	7.6 (6.0 - 9.3)
Degree	9.0 (7.3 - 10.9)	7.3 (5.7 - 9.0)
Occupational status	n=1038	n=1030*
Employed	51.9 (48.8 - 55.0)	99.8 (99.3 - 100.0)
Unemployed	48.1 (45.0 - 51.2)	0.2 (0 - 1.0)

* Due to missing data

The prevalence of ECC was 56.3% (95% CI 53.1 - 59.3). All 1038 data points were used in the SEM. In the initial structural model, none of the pathways directed to or from the family brushing latent variable were significant, therefore, this latent variable was omitted from the final model. The model fit indices of the final model were within acceptable levels. All model fit indices improved in the final model. (Satorra Bentler χ^2=39.2, RMSEA=0.03, GFI=0.93, AGFI=0.92, CFI=0.9, SRMR=0.047).

Sweet consumption behaviour (β=0.22, p=0.00) and child dental attendance pattern (β=0.10, p=0.03) had positive direct effects, and oral hygiene behaviour (β=-0.36, p=0.00) had a negative direct effect on ECC (Table 2).



Significant pathways (p<0.05) in bold lines
Non-significant pathways in dashed lines
Standardized β coefficients are shown for significant pathways

***Figure 1**. Final Structural Model of SEM Analysis illustrating the pathways between latent variables.*

Table 2. Direct effects of the proximal determinants on ECC in SEM

	Standardized Estimate (SD)	*p*
Child sweet consumption	0.22 (0.03)	0.00*
Child oral hygiene behaviour	-0.36 (0.02)	0.00*
Child dental attendance pattern	0.10 (0.02)	0.03*

* p <0.05

In turn, there were total effects from oral health-related knowledge (β=-0.16, p=0.02), oral health-related attitudes (β=-0.17, p=0.02), permissive parenting (β=0.25, p=0.00), and family sweet consumption (β=0.17, p=0.01) on child sweet consumption (Table 3). There were direct effects from permissive parenting (β=0.26,p=0.00), and family sweet consumption (β=0.17, p=0.01).

There were total effects from knowledge (β=0.21, p=0.00), attitudes (β=0.23, p=0.00), authoritative parenting (β=0.17, p=0.00), permissive parenting (β=-0.55, p=0.00) and self-efficacy (β=0.23, p=0.00) on child oral hygiene (Table 3). There were direct effects from permissive parenting (β=-0.46, p=0.00) and self-efficacy (β=0.23, p=0.00). The dental attendance pattern had total effects on knowledge (β=0.18, p=0.00) and permissive parenting (β=-0.16, p=0.00).

Discussion

This study focused on secondary and proximal level determinants of ECC. There were direct relationships between sweet consumption, oral hygiene behaviour and dental attendance pattern with ECC.

Child dental attendance was positively associated with ECC, which might be counter intuitive. The items used to measure dental attendance considered the reasons for the last dental visit, duration and treatment received at the last visit, and accessibility to the dental clinic. There may be reverse causality if children visited a dental clinic for treatment after getting the disease. Other studies have reported similar results (Qin *et al*., 2019; Qiu *et al*., 2014).

The strongest underlying determinants of child sweet consumption behaviour were parenting style and family sweet consumption behaviour. It seems likely that young children would tend to consume sweets with other family members at home and will be directly influenced by the sweet consumption of family members. Buldur (2020) also reported a strong relationship between parental and child's oral health. A permissive parenting style also predicted sweet consumption. When parents do not restrict unhealthy behaviours by their children, they may continue that behaviour.

Table 3. Direct and indirect effects of proximal determinants on second line of determinants in the final SEM.

	Proximal Determinant									*ECC*
	Sweet Consumption			*Oral Hygiene*			*Dental Attendance*			
	Direct	*Indirect*	*Total*	*Direct*	*Indirect*	*Total*	*Direct*	*Indirect*	*Total*	*Total*
Knowledge										
Standardized estimate	-0.07	-0.09	-0.16	0.03	0.18	0.21	0.14	0.04	0.18	-0.09
p	0.34	0.43	0.02*	0.71	0.00*	0.00*	0.02*	0.19	0.00*	0.00*
Attitudes										
Standardized estimate	-0.10	-0.07	-0.17	0.11	0.12	0.23	0.02	0.03	0.05	-0.12
p	0.15	0.03*	0.02*	0.13	0.00*	0.00*	0.74	0.07	0.35	0.00*
Authoritative parenting style										
Standardized estimate	0.02	0.00	0.02	0.12	0.05	0.17	0.03	0.00	0.03	-0.05
p	0.79	0.72	0.74	0.14	0.01*	0.04*	0.70	0.98	0.68	0.14
Authoritarian parenting style										
Standardized estimate	-0.02	0.00	-0.02	-0.14	0.02	-0.12	0.03	0.00	0.03	0.04
p	0.81	0.73	0.82	0.06	0.15	0.13	0.67	0.92	0.66	0.20
Permissive parenting style										
Standardized estimate	0.26	-0.01	0.25	-0.46	-0.08	-0.55	-0.16	0.00	-0.16	0.23
p	0.00*	0.72	0.00*	0.00*	0.00*	0.00*	0.00*	0.92	0.00*	0.00*
Self Efficacy										
Standardized estimate	0.02	NA	0.02	0.23	NA	0.23	0.00	NA	0.00	-0.08
p	0.72	NA	0.72	0.00*	NA	0.00*	0.92	NA	0.92	0.00*
Family Sweet consumption										
Standardized estimate	0.17	NA	0.17	NA	NA	NA	NA	NA	NA	0.04
p	0.01*	NA	0.01*	NA	NA	NA	NA	NA	NA	0.01*

*= p <0.05
NA= Not Applicable

Maternal oral health-related knowledge and attitudes did not directly affect sweet consumption behaviour but were mediated via the parenting style and family sweet consumption. Two Chinese studies have also failed to find a relationship between caregivers' oral health-related knowledge and the oral health practices of their five-year-old children (Qin *et al*., 2019; Qiu *et al*., 2014).

Maternal oral health-related self-efficacy was not associated with child sweet consumption. Conversely, a study among similarly aged children in England reported a relationship (Litt *et al*., 1995). However, the scale used to measure self-efficacy differed from that used in the present study.

The strongest determinants of children's oral hygiene behaviour were parenting style and maternal oral health-related self-efficacy. These factors mediated the effect of oral health-related knowledge and attitudes.

Family oral hygiene behaviour was omitted from the structural model as it was not significant in preliminary analyses. The family's oral hygiene behaviour may not influence child tooth brushing behaviour if toothbrushing is not performed collectively within the family. Furthermore, permissive parenting may allow children to behave as they like. Although parents understand that toothbrushing is beneficial, they cannot achieve best practice for their child's oral hygiene because of their parenting style. Kumar et al. (2017) reported that power assertion parenting was negatively associated with child oral hygiene behaviour, However, we found that permissive parenting style was negatively associated with oral hygiene behaviour. Permissive parenting was negatively related to dental child attendance. This finding is in concordance with results of a study with older children in Turkey that found authoritative parenting to be related to child dental attendance (Buldur, 2020).

Overall, the effects of maternal oral health-related knowledge and attitudes were mediated via parenting style, family sweet consumption and maternal oral health-related self-efficacy which affected oral health behaviours to develop ECC. Qin et al. (2019) also reported that oral health-related knowledge had no direct relationship with dietary or toothbrushing behaviours.

It is essential to target these underlying factors to control ECC. Approaches targeting upstream health promotion activities, such as taxation and restricting sugar-sweetened beverages, may prove beneficial (World Health Organization, 2018).

Whilst this study recruited a large probability sample and used valid and reliable data collection instruments it has several limitations. The findings should only be generalised to other districts with care and our cross-sectional design restricts causal inference. Incorporation of more distal upstream factors would have increased the explanatory power of the model and may have suggested more fundamental approaches to promoting the oral health of Sri Lankan children. Nevertheless, the findings can be utilized in regional-level program planning to reduce ECC among preschoolers.

In conclusion, parenting style, family sweet consumption and maternal self-efficacy were influential second-line determinants that affected oral health behaviours of child sweet consumption, oral hygiene and dental attendance in the development of ECC.

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