



Small-area contextual effects on children's dental caries in Alberta: a multilevel analysis

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Abstract

Objectives The objective of this study was to examine the presence of small-area-level effects on children's dental caries in Alberta, Canada, where dental public health programming is targeted in nature, based on an area-level measure of socio-economic circumstances.

Methods This cross-sectional study included data on tooth decay (from an intra-oral examination conducted by dental hygienists at school) and socio-demographic and behavioural information (from a parent questionnaire) from 5677 grade 1 and 2 schoolchildren attending schools in public or Catholic school systems in Calgary and Edmonton in 2013/2014. Area-level socio-economic circumstances were quantified using the Pampalon Material Deprivation Index derived from census data, applied to the dissemination area (DA) of the child's school. The outcome variable was presence (vs. absence) of tooth decay (cavitation). Data were analyzed using multilevel modeling with two levels: individual level (level 1) and school dissemination area (DA) (level 2).

Results We observed a small but statistically significant area-level effect on children's caries experience, above and beyond individual-level characteristics.

Conclusion Study findings are relevant to dental public health programming in Alberta and other jurisdictions that use targeted strategies. Multilevel interventions, including universal approaches, are necessary to reduce inequities in children's dental caries.

Résumé

Objectifs Examiner la présence d'effets de petite région sur les caries dentaires des enfants en Alberta, au Canada, où les programmes publics de santé dentaire sont ciblés de nature, d'après un indicateur régional de la situation socioéconomique.

Méthode Cette étude transversale a inclus des données sur la carie dentaire (venant d'un examen intra-buccal mené par des hygiénistes dentaires dans les écoles) et des informations sociodémographiques et comportementales (venant d'un questionnaire auprès des parents) concernant 5 677 enfants d'âge scolaire de 1^e et de 2^e année fréquentant les écoles du système public ou du système catholique de Calgary et d'Edmonton en 2013-2014. La situation socioéconomique régionale a été chiffrée à l'aide de l'indice de défavorisation matérielle de Pampalon dérivé des données du Recensement, lesquelles ont été appliquées à l'aire de diffusion (AD) des écoles des enfants. Le résultat a été la présence (c. l'absence) de carie dentaire (cavitation). Les données ont été analysées par modélisation multiniveaux selon deux niveaux : la personne (niveau 1) et l'AD de l'école (niveau 2).

Résultats Nous avons observé un effet régional léger mais significatif sur l'expérience de caries des enfants, au-delà des caractéristiques individuelles.

Conclusion Les constatations de l'étude sont pertinentes pour les programmes de santé dentaire en Alberta et dans d'autres administrations qui utilisent des stratégies ciblées. Des interventions multiniveaux, y compris des approches universelles, sont nécessaires pour réduire les iniquités dans les caries dentaires des enfants.

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Mots-clés Effets de petite région · contextuel · caries dentaires · enfant

Introduction

Dental caries is the most common chronic disease in both children and adults in Canada (CDA 2017). Severely decayed teeth can have a substantial negative impact on children's health and well-being (Sheiham 2006). Although there have been significant improvements over the past 40 years in Canada, dental caries remains a significant public health problem, with a high prevalence (over half of Canadian children are affected) and persistent socio-economic inequities (CAHS 2014).

A population health approach emphasizes the multilevel nature of health determinants (PHAC 2004). Fisher-Owens et al. (2007) provided a conceptual framework of children's oral health determinants, which specifies determinants at the child, family, and community levels. The role of factors measured at the individual and family levels has been well documented. For instance, frequent sugary consumption, poor dental hygiene practices, inadequate dental insurance and low use of dental care, ethnic minority group status, lower level of parental education, and lower family income have all been identified as risk indicators for childhood caries (Shi et al. 2018; Hudson et al. 2007; Mobley et al. 2009). However, an individual's risk of illness cannot be considered in isolation from the risk distribution of the population to which they belong, i.e., the community's context (Rose 1985). One contextual factor that has been frequently investigated is the socio-economic status (SES) of the area in which individuals live (Diez Roux 2001). However, people with lower SES often live in socio-economically disadvantaged areas while people with higher SES often live in socio-economically advantaged areas (Merlo 2003). The ensuing confounding of area- and individual-level SES presents a conceptual and methodological challenge for health research.

To study contextual effects, it is necessary to disentangle the effects of characteristics of the area (contextual effects) from the effects of individual-level characteristics of the people within the area (compositional effects), which can be achieved using multilevel modeling (Merlo 2003).

There are a few international studies that used multilevel modeling to study contextual effects on dental health (Tellez et al. 2006; Aida et al. 2008; Antunes et al.

2006). For instance, one study in the United States demonstrated that the neighbourhood's context (measured by a socio-economic composite score, and presence of dentists, grocery stores, and churches) had independent effects on dental caries severity among children under age 6 years, above and beyond individual-/family-level characteristics including age, employment status, family income, perceived availability of dental services, perception of mouth and teeth, reported sugar intake, and social support (Tellez et al. 2006).

However, there are no published Canadian studies that evaluate contextual effects on dental health, which constitutes an important knowledge gap. In Canada, the financing and delivery of dental care is overwhelmingly situated in the private sector (CAHS 2014), which presents considerable cost barriers to populations for whom conventional private dental care is inaccessible. Almost all of the limited public financing of dental care that is available in Canada (approximately 5% of the total dental financing) is targeted to groups defined as economically marginalized and is often delivered in the private sector through public forms of third-party payments (Shaw and Farmer 2015).

In Alberta, children's dental public health programs are delivered to target groups defined based on the SES of the dissemination area (DA) where schools are located (see details in the Methods section) (Figueiredo et al. 2016). A dissemination area is the smallest (400–700 individuals) administrative area unit in the national census (Statistics Canada 2013). By investigating school DA's contextual effects on children's dental caries, this study will shed light on the relevance and accuracy of the criteria currently used for selecting recipient areas. The specific objective was to examine geographic variation in children's dental caries, and whether, or the extent to which, such variation was attributable to contextual effects of school DA, to different individual compositions of DAs, or both.

Methods

Data source

The study population included children attending grades 1 and 2 in the public or Catholic school system in Calgary and

Edmonton, Alberta, Canada, during the 2013/2014 school year. Data were collected for a larger study (see McLaren et al. 2017), using multistage cluster probability sampling.¹ All grade 2 students from all participating schools and all grade 1 students from some of those schools were invited to participate.²

Data collection included an intra-oral examination and a parent questionnaire. The exam was conducted at school by registered dental hygienists, who were trained and calibrated for the main study. Based on exam data, the deft/DMFT index was determined for each child (Warren et al. 2002); that index refers to the total number of decayed (untreated caries) (d/D), extracted/missing due to caries (e/M) (as distinct from missing for reasons other than caries, such as natural exfoliation), and filled due to caries (f/F) teeth, for primary (lowercase) and permanent (capitalized) teeth. The hard-copy questionnaire, which was distributed at school, completed by parents, and returned via mail, included items in the following domains: parent reports of their child's dental health; child's use of dental health professionals; child's food and beverage consumption; child's use of fluoride supplements and drinking water source; and socio-demographic information. The present study received approval from the Conjoint Health Research Ethics Board at the University of Calgary (ID REB17-1918).

Study measures

Individual- and family-level variables

The outcome variable for this study was *presence (vs. absence) of decay experience* (i.e., deft/DMFT>0), that is, whether a child had at least one primary or permanent tooth that was decayed, extracted/missing due to decay, or filled (vs. not). The threshold for presence of dental decay experience in this index is the detection of caries that has caused the enamel of the tooth to be cavitated. Elsewhere (Shi 2019), we also considered another outcome, namely, caries experience (i.e., count of deft/DMFT), and the findings for the two outcomes, with respect to contextual effects, were largely similar.

Most individual- and family-level explanatory variables, selected to align with the conceptual framework provided by Fisher-Owens et al. (2007), were derived from the parent questionnaire. Demographic variables included age, gender, and ethnicity. Individual-/family-level SES variables included dental insurance, highest parental education level, and

housing tenure. Dietary and tooth hygiene behaviours were measured using reported sugar-sweetened beverage consumption and daily frequency of tooth brushing, respectively. Finally, child's use of dental care services was measured using routine dental visit in the past year (yes/no) from the parent questionnaire, and presence of dental sealants (yes/no), which was assessed during the oral exam.

Contextual-level variable

We used school dissemination area (DA) (i.e., the DA in which the child's school was located) to operationalize "small area" or "neighbourhood". The choice of school (rather than residential) DA was deliberate: in Alberta, selection of target schools for dental public health programming is based on socio-economic characteristics (see below) of DAs where schools were located (Figueiredo et al. 2016). Although schoolchildren may live outside of the DA in which their school is located, we deemed it important to focus on school DA to be consistent with, and derive relevant implications for, dental public health service delivery in Alberta. In Canadian urban areas, each postal code is nested within a DA. Each child belongs to a school with a corresponding school postal code, which permits linking individual-level data to DA material deprivation quintile.

The socio-economic characteristics of each school DA were operationalized using DA-level material deprivation quintile, with Q1 representing the least deprivation (highest socio-economic characteristics) and Q5 representing the most deprivation (lowest socio-economic characteristics). This measure is derived from the Pampalon Material Deprivation Index, which is used by Alberta Health Services to select target areas for service delivery. This composite index is based on three DA-specific socio-economic indicators from the national census, all of which pertain to the population age 15 years and older: (i) proportion without a high school diploma or equivalent; (ii) employment to population ratio; and (iii) average income. Briefly, the composite material deprivation index is a factor score (continuous) derived from a principal component analysis of the three indicators, which is then divided into quintiles, and available for all DAs across the province (Pampalon et al. 2009). Using that province-wide information, a material deprivation factor score and a quintile indicator were applied to each DA in the study sample.

Statistical analysis

All data management and analyses were carried out using Stata 14. Two-tailed *p* values of less than 0.05 were considered statistically significant, and 95% confidence intervals (CIs) for point estimates are provided. Sampled children with missing values were excluded from analyses, and all analyses were based on the subset with complete data on all study variables.

¹ In Calgary and Edmonton, respectively: overall school-level response rates were 57.3% and 54.1%; overall student-level response rates within participating schools were 49.1% and 47.0%. These student-level response rates reflect those with both oral exam and questionnaire data. The response rate for those with questionnaire data only was slightly higher (54% overall).

² Briefly, the primary population of interest for the larger study (McLaren et al. 2017) was grade 2 students, but a smaller number of grade 1 students were also sampled to permit comparison with the Canadian Health Measures Survey oral health component, which included 6 year olds (approximately grade 1).

Sampling weight

To account for potential imbalances in participation rates in DAs and to enhance the participants' representativeness of the

$$\text{Weight-id} = \text{weight for each child} = \frac{\text{total number of grade 1 and/or grade 2 students in a given DA}}{\text{number of grade 1 and/or grade 2 students sampled in a given DA}}$$

Analysis

Descriptive statistics of all study variables were examined. Multilevel logistic regression was used to estimate the relative amount of variance at each level (i.e., schoolchildren [level 1], and school DA [level 2]) in the probability of having tooth decay experience. Four consecutive models were run. Model 1 was fit without any independent (explanatory) variables, with only level 2 intercepts allowed to vary. Model 2 fitted individual-/family-level explanatory variables, holding their coefficients fixed. Model 3 fitted the contextual-level variable (i.e., DA material deprivation quintile) instead of individual-/family-level variables. The last model fitted both individual-/family-level and contextual-level explanatory variables. For each model, we present the variance partition coefficient (VPC), which is defined as the percentage of total individual variance in the individual health outcome that is between second-level units. In this study, the VPC indicates whether, and to what extent, dental caries experience was more similar among children in the same DA (i.e., within-DA clustering) than among children from different DAs. The higher the VPC, the greater the within-DA clustering of the health outcome, in this case, presence of dental caries experience (Li et al. 2008). (See [Appendix](#) for VPC calculation in multilevel logistic regression.)

Results

Of the 6884 participants in the larger study who had data from both the parent questionnaire and the oral exam, 36 children were excluded due to missing data on the contextual-level variable (i.e., Pampalon material deprivation) and 1171 were excluded due to either missing data on individual-level variables or to an ethnic group selection that fell below 100 in total (i.e., Japanese, Korean, Southeast Asian, and West Asian), which was deemed to be a minimum number for interpretation of this variable. Data from a total of 5677 students attending 241 schools located in 220 DAs in Calgary and Edmonton during the 2013/2014 academic year were analyzed.

Table 1 shows the characteristics of the sample, overall and stratified by DA material deprivation quintile. Overall, the mean age of the sample was 6.9 years and included an almost equal

underlying population, a probability weight for each child was developed and applied. The weight was constructed as follows:

proportion of boys and girls. The percentage of children with tooth decay experience increased with increasing DA-level material deprivation (e.g., 53% of children had decay experience in quintile 1 vs. 65% in quintile 5). Although more prevalent in higher DA-level quintiles, dental caries experience was not exclusively found in the most materially deprived quintiles but rather was present across all deprivation quintiles.

Table 2 presents the results of the four multilevel regression models. The VPC estimate for model 1 suggests that around 12% of total individual variance in the probability of having decay experience was attributable to variation between school DAs. In model 2, school DA-level variance was reduced by 23% compared with model 1 by adjusting for individual-/family-level explanatory variables. This indicates that 23% of school DA-level variance is due to differences in individual-/family-level characteristics (i.e., compositional effects); the remaining school DA-level variance reflects the true contextual effects of school DA. Model 3 shows that school DA-level material deprivation explained only 12% of school DA-level variance. Finally, in model 4, after adjusting for both individual-/family-level and school DA-level variables, the VPC estimate decreased from 9.4% (model 2) to 9.1%. This slight decline further supports an independent contextual effect of school DA, although the school DA material deprivation quintile only explained a small amount of this effect.

A sensitivity analysis was conducted to evaluate whether including low participation school DAs (which could unduly impact results, if they have much better or worse dental health than others) would influence study results. Specifically, 26 school DAs (326 students), where less than 10% of eligible children in a given grade were sampled, were excluded from sensitivity analysis. Results (not shown) indicate that including children from low participation school DAs may potentially overestimate the school DA-level variance to a small extent.

Discussion

Consistent with many existing ecological studies (Muirhead and Marcenes 2004; Gillcrist et al. 2001), descriptive statistics

Table 1 Characteristics of study sample of grade 1 and 2 schoolchildren attending school in the public or Catholic school system in the urban areas of Calgary and Edmonton in 2013/2014, by quintiles of Pampalon material deprivation of school DA. Values are mean or percentage (weighted sample)

Variables	Level of Pampalon material deprivation					
	Total <i>n</i> _{neighbourhood} =220 <i>n</i> _{student} =5677	1st quintile <i>n</i> _{neighbourhood} =49 <i>n</i> _{student} =1401	2nd quintile <i>n</i> _{neighbourhood} =37 <i>n</i> _{student} =1341	3rd quintile <i>n</i> _{neighbourhood} =43 <i>n</i> _{student} =1092	4th quintile <i>n</i> _{neighbourhood} =41 <i>n</i> _{student} =749	5th quintile <i>n</i> _{neighbourhood} =50 <i>n</i> _{student} =1094
Individual outcomes						
Presence of dental caries, %	57.8	52.9	56.0	54.9	60.4	65.4
Count of deft/DMFT, mean	2.8	2.3	2.6	2.7	3.2	3.4
Socio-demographic variables						
Age in years, mean	6.9	6.9	7.0	6.8	6.9	6.9
Male, %	50.4	48.3	53.0	49.1	51.8	50.0
Ethnicity identity, %						
White	48.5	62.0	57.5	46.4	43.8	30.4
South Asian	14.9	8.2	12.8	14.5	17.3	22.9
Filipino	7.5	5.9	4.9	9.1	10.5	8.2
Chinese	5.1	5.4	4.3	6.4	3.3	5.6
Black	5.1	2.5	3.7	4.6	5.5	9.4
Arab	4.1	2.1	5.1	2.8	6.9	4.2
Latin American	2.9	3.1	1.3	3.5	2.5	4.0
Indigenous	2.1	1.0	1.3	1.5	3.1	3.9
Mixed ethnic	9.8	9.8	9.1	11.2	7.1	11.4
Dental insurance type, %						
No insurance	16.6	13.2	13.1	15.3	19.4	22.3
Employer or private	73.3	82.2	81.0	72.5	66.7	61.7
Public	10.1	4.6	5.9	12.2	13.9	16.0
Highest level of parent's education (≤high school graduate), %	15.0	5.5	9.1	13.7	20.7	27.9
Housing tenure, %						
Own, with no mortgage	9.1	12.2	11.3	8.7	6.3	6.1
Own, with mortgage	59.8	69.0	68.6	59.1	50.1	48.7
Rent	31.1	18.8	20.1	32.2	43.6	45.2
Caries-related behaviours						
Brushing teeth at least once per day, %	62.5	68.3	62.9	63.7	57.9	58.4
Sugar-sweetened beverage consumption (high level), %	24.6	12.0	16.3	25.6	31.4	40.4
One or more routine dental visits in the past year, %	85.9	91.4	88.9	86.7	82.7	78.5
Presence of dental sealants, %	23.7	22.1	21.8	21.7	30.0	24.4

from this study showed that the probability of having tooth decay experience among grade 1 and 2 schoolchildren in Calgary and Edmonton increased with increasing small-area material deprivation, in this case focusing on the dissemination area in which the child's school is located. However, a main limitation of ecological studies is that they use data aggregated to a single geographic scale and hence are not able to discern whether or the extent to which health differences between areas reflect compositional effects, contextual effects, or some combination of the two. Applying a stepwise

multilevel analysis approach to build on those limitations, the present study showed that while part of this geographic variation reflects varying population compositions of DAs, there remains a significant DA-level variance (and VPC) that indicates the presence of true contextual effects of school DAs. This finding is consistent with some studies from other countries (Tellez et al. 2006; Aida et al. 2008; Antunes et al. 2006) that demonstrated small but statistically significant area contextual effects on dental health outcomes and it extends this knowledge to the Canadian context.

Table 2 Multilevel logistic regression analysis of the presence of decay experience for grade 1 and 2 schoolchildren in Calgary and Edmonton in school year of 2013–2014. Values are given as odds ratios (ORs) and 95% confidence intervals (CIs) unless stated otherwise

	Model 1 OR (95% CI)	Model 2	Model 3	Model 4
Fixed effects				
Age		1.2 (1.1, 1.4)		1.2 (1.1, 1.4)
Female (v. male—reference)		0.9 (0.8, 1.0)		0.9 (0.8, 1.0)
Ethnicity identity				
White		Reference		Reference
South Asian		1.4 (1.1, 1.8)		1.4 (1.1, 1.8)
Filipino		2.9 (2.1, 4.1)		2.9 (2.1, 4.1)
Chinese		3.2 (2.4, 4.2)		3.2 (2.4, 4.2)
Black		1.3 (0.8, 1.9)		1.3 (0.8, 1.9)
Arab		3.8 (2.2, 6.4)		3.8 (2.2, 6.3)
Latin American		1.4 (0.9, 2.0)		1.4 (0.9, 2.0)
Indigenous		3.0 (1.6, 5.7)		3.0 (1.6, 5.7)
Mixed ethnic		1.5 (1.2, 1.9)		1.5 (1.2, 1.9)
Household educational attainment (\leq high school graduate v. $>$ high school)		1.3 (1.0, 1.6)		1.3 (1.0, 1.6)
Housing tenure				
Own, with no mortgage		Reference		Reference
Own, with mortgage		1.1 (0.9, 1.4)		1.1 (0.9, 1.4)
Rent		1.3 (1.0, 1.8)		1.3 (1.0, 1.8)
Dental insurance type				
No insurance		Reference		Reference
Employer or private insurance		0.9 (0.8, 1.2)		0.9 (0.8, 1.2)
Public insurance		1.2 (0.9, 1.7)		1.2 (0.9, 1.7)
Brushing teeth at least once per day (yes v. no)		0.8 (0.7, 0.9)		0.8 (0.7, 0.9)
Sugar-sweetened beverage consumption (high v. median/low)		1.3 (1.1, 1.6)		1.3 (1.1, 1.6)
Dental visits in the past year (yes v. no)		1.3 (1.0, 1.6)		1.3 (1.0, 1.6)
Presence of dental sealants (yes v. no)		1.7 (1.4, 2.0)		1.7 (1.4, 2.0)
Material deprivation level				
Quintile 1 (least deprived)			Reference	Reference
Quintile 2			1.1 (0.8, 1.4)	1.0 (0.8, 1.2)
Quintile 3			1.0 (0.7, 1.3)	0.8 (0.6, 1.1)
Quintile 4			1.3 (1.0, 1.7)	0.9 (0.7, 1.3)
Quintile 5 (most deprived)			1.7 (1.3, 2.2)	1.2 (0.9, 1.5)
Random effects				
DA-level variance (95% CI)	0.5 (0.3, 0.7)	0.3 (0.2, 0.6)	0.4 (0.3, 0.6)	0.3 (0.2, 0.5)
Variance partition coefficient (VPC)	11.9%	9.4%	10.7%	9.1%
Explained DA-level variance (%) (relative to model 1)		23.3%	12.0%	26.3%

This study also observed a significant association between DA material deprivation quintile and presence of dental caries experience (model 3); however, the association disappeared after additionally adjusting for individual-/family-level variables in the final model. In contrast, some other multilevel studies (Marinacci et al. 2004; Kavanagh et al. 2005) demonstrated an independent contribution of area-level socio-economic context to individual dental health outcomes. One possible explanation is that, in contrast to studies that only

adjusted for demographic variables and individual-level SES (Marinacci et al. 2004), this study included caries-related behaviours and routine dental care variables, in addition to individual-level SES. Because the effects of SES on dental health outcomes may be partially mediated by sugar consumption and use of dental care services (Hudson et al. 2007), it is likely that this added information reduced the independent contribution of area-level material deprivation to dental caries outcome in the present study. Another possible reason for the

discrepancy is that, because the DA material deprivation quintile is—as discussed in the Methods section above—constructed by combining three SES indicators (i.e., employment, income, and education), it intertwines with personal SES. Statistically speaking, multilevel modeling is able to disentangle contextual effects from compositional effects; however, from a conceptual perspective, distinction between these two types of effects is not clear-cut.

Although the significant association between DA material deprivation quintile and presence of dental caries experience disappeared in the final model, the positive DA-level variance and VPC estimate indicate the existence of independent contextual effects of school DA even after additionally adjusting for individual-/family-level variables. The slight decline of the VPC estimate (from model 2 to final model) further suggests this independent contextual effect, although the measure of school DA material deprivation quintile only explained a very small amount of these contextual effects. Thus, independent contextual effects on children's dental caries, other than DA material deprivation, in our setting exist and are non-negligible. Examples could include the number of dentists in a community or the fluoride concentration in the public drinking water supply (Tellez et al. 2006; Aida et al. 2008). Future research may consider using more direct measurement of area attributes rather than, or in addition to, census-based aggregate measure used in the present study.

Study strengths and limitations

This study has several strengths. First, its use of a multilevel analytic approach, by providing different and complementary information, offers better understanding of inequalities in children's dental caries, compared with single-level ecological studies. Second, study findings are relevant to dental public health programming in our context of Alberta, and likely in other provinces as well, because targeted service delivery is a dominant approach in dental public health across the country (Shaw and Farmer 2015). Findings are especially pertinent to other Canadian jurisdictions that employ area-based strategies using readily available indicators such as DA-level material deprivation quintile.

The study also has limitations. First, like many multilevel analyses, the present study used a cross-sectional design, focused on the characteristics of the area where the child attended school at one point in time, with no information about exposure to material deprivation across the life course (O'Campo 2003). Second, individual data were collected during 2013/2014, while the DA material deprivation quintile was derived from the 2006 Canadian census, which constitutes a 7-year gap between individual-level and contextual-level data. The 2006 Pampalon Index version was used due to concern about low quality (low response rate and high level of missing values) of the 2011 version when the long-form

census was cancelled. However, an analysis by Alberta Health Services showed that most of the changes from one material deprivation category to another (i.e., when a DA does not have the same Pampalon value in 2011 as in 2006) occurred between adjacent categories (AHS 2016). More importantly, the 2006 census data are what the provincial dental public health programming was using for area-targeted services at the time of data collection (personal communication, AHS Dental Public Health Officer, 2012).

Conclusion

Overall, our results showed that school DA context contributed a small but statistically significant effect on dental caries experience in our context, which supports the Alberta Health Services' practice of selecting schools based on the DA in which they are located. On the other hand, they also showed that, although the highest risk of dental caries was found in the most materially deprived DAs, the large number of children at risk was more thinly spread across all deprivation quintiles. This is consistent with Geoffrey Rose's prevention principle, whereby a large number of people at small risk constitutes more disease burden than a small number at high risk, on the basis of which he argued for the importance of a population-level strategy (i.e., a prevention approach that addresses causes of incidence across the population as a whole) (Rose 1985). A high-risk prevention strategy, which focuses exclusively on the highest risk (or most materially deprived) areas, would miss many affected children. This has implications for jurisdictions like Alberta, where dental public health activities are targeted in nature, based on area (school DA)-level material deprivation (Figueiredo et al. 2016). Although the targeted approach is intended to provide services in areas where there is less access to dental services, and thus to work towards equity, it aligns with what Hilary Graham describes as a *disadvantages* conceptualization of equity, where the focus is on improving the health of poor groups. From a population health perspective, it would be preferable to adopt a *gradients* conceptualization of equity, which aims to address the association between socio-economic circumstances and health across the population (Graham 2004).

Specifically, in addition to targeted strategies that exclusively focus on children in high-risk areas (such as the preschool/school fluoride varnish program delivered by Alberta Health Services) (Figueiredo et al. 2016), a universal approach would also benefit and support children at low or moderate risks, so that the dental health of the entire population can be improved (Zulman et al. 2008). Examples of such a strategy include community water fluoridation, which is present in Edmonton but not in Calgary (McLaren et al. 2017), and public policy to reduce dietary sugar intake at the population level (Weijs et al. 2019). Overall, study results

support the need for multilevel interventions to reduce inequities in children's dental caries.

Appendix. Calculation of variance partition coefficient (VPC) in multilevel logistic regression

In a multilevel linear model, both the between-subject (the first level) and the between-cluster (the second level) variations can be derived directly from the fitted model and the VPC is intuitively easy to understand:

$$\text{VPC} = \frac{\text{between-cluster variation}}{\text{between-subject variation} + \text{between-cluster variation}}$$

However, VPC is less straightforward to understand and calculate in multilevel regression for outcome measures that are not continuous. For binary outcomes (presence of dental caries), the VPC was calculated based on the latent response formulation, as it is the most widely adopted approach in applied work. This formulation assumes that a latent continuous response underlies the observed binary response and it is on the basis of this latent continuous response that the VPC is calculated and interpreted (Li et al. 2008) (Merlo et al. 2005). The VPC for a binary outcome is computed as:

$$\text{VPC} = \frac{\text{between-cluster variation}}{\text{between-cluster variation} + \pi^2/3},$$

where $\pi^2/3$ denotes the variance of a standard logistic distribution.

Code availability Not applicable.

Author contributions CS and LM conceptualized the study. All authors contributed to data collection, analysis, or interpretation. CS and LM led the writing of the work and FT, SP, PF, and LM revised it critically for important intellectual content. All authors approve the final submitted version and agree to be accountable for all aspects of the work.

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Declarations

Ethics approval This study received approval from the Conjoint Health Research Ethics Board at the University of Calgary (ID REB17-1918).

Consent to participate Please refer to “Ethics approval”.

Consent for publication Not applicable.

Conflict of interest The authors declare that they have no conflicts of interest.

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