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Impact of socioeconomic inequalities on dental caries in deprived children: a multilevel analysis

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Objectives: Inequalities have been reported between high, middle and low socioeconomic position (SEP) children. However, the effect of contextual and individual SEP on existing inequalities among socioeconomically deprived children varies between local contexts. The aim of this study was to assess the impact of contextual and individual SEP on individual caries experience among socioeconomically deprived children in Chile. ***Methods***: Cross-sectional multilevel analysis of data from the 2015 electronic register of the National Board of School Aid and Scholarships (JUNAEB) of Chile. The contextual variables were the municipality Human Development Index (HDI) and rurality index. Individual variables included gender, living in extreme poverty and school grade. Multilevel negative binomial models assessed their impact on DMFT/dmft. ***Results***: 112,429 children in 255 municipalities were included. Overall, contextual SEP (HDI) was not associated with caries experience in the primary or permanent dentition. Individual SEP (living in extreme poverty) was associated with caries experience in both dentitions. The proportion of children living in extreme poverty with caries experience in the primary teeth was 17% higher than children not living in extreme poverty (PR 1.17; 95% CI 1.15-1.19), while for children with permanent teeth it was 9% higher (PR 1.09; 95% CI 1.08-1.11). ***Conclusion***: These findings could support the development of health strategies focused on individual SEP to efficiently reduce oral health inequalities among socioeconomically deprived children.

Keywords*: Socioeconomic factors, child, poverty, caries*

Introduction

Dental caries is considered a major public oral health problem worldwide, with severe and long-lasting consequences on children and their families (Peres *et al.*, 2007; Zaror *et al.*, 2022). Its distribution varies worldwide, with prevalence in up to 90% of children and adolescents in South America (Kassebaum *et al.*, 2017).

Current caries control is focused on eliminating etiological factors. However, this biological approach has been insufficient to address the prevalence of the disease in the broader population. From this perspective, knowing the social determinants that influence the process can be helpful in controlling this disease in the population. The social determinants framework for oral health inequalities provides contextual structural determinants an essential role in shaping the behaviours that cause oral diseases among populations (Watt and Sheiham, 2012). These contextual factors shape the individual socioeconomic position (SEP), which in turn influences behavioural, psychosocial and biological factors resulting in oral health inequalities. Contextual factors that have been associated with dental caries inequalities include the Human Development Index (HDI) and Rurality Index, among others. The latter with strong evidence of its association with dental caries in Chile (Giacaman *et al.*, 2018).

The relationship between individual SEP and dental caries has been studied extensively (Costa *et al.*, 2012). Evidence has been found of an association between low levels of education, social class and income with poor oral health. However, the association between contextual SEP and oral conditions varies across communities. A systematic review by Schwendicke et al. (2015) found that caries experience was distributed more disproportionately in high-income than low-income countries. Contextual differences can also be found within countries. Pattussi et al. (2006) found that individual SEP was associated with dental caries among Brazilian adolescents, rather than neighbourhood poverty. Conversely, Poon et al. (2015) reported that caries rates were lower in high-SEP neighbourhoods than low-SEP among 4-6-year-olds in British Columbia. Multilevel models allow investigation of the effects of both individual and contextual SEP on oral health independently. In studies using this approach, the socioeconomic context has been associated with dental caries at regional, municipality and neighbourhood level after adjusting for individual-level SEP. However, there are differences in the magnitude of dental caries inequalities between geographical areas and age groups (Priestnitz *et al.*, 2016; Lee *et al.*, 2012). Although the evidence shows that social determinants explain inequalities in the general population, it is not clear whether these

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differences remain in more homogeneous socioeconomic groups. This emphasises the importance of analysing the contextual SEP effect in different settings to support locally appropriate oral health policy-making, especially for the most vulnerable groups.

Oral health inequalities have been reported between high, middle and low SEP children (Peres *et al.*, 2019). Furthermore, studies have evaluated oral health inequalities among individuals within underprivileged populations, such as those living in extreme poverty. These studies have found some evidence of the existence of oral health gradients among deprived children suggesting heterogeneity within this sub-population (Calvasina *et al.*, 2018; Mathur *et al.*, 2014, Squassi *et al.*, 2008). There is still a lack of evidence on the differentiated effect that individual and contextual SEP plays on existing oral health inequalities in groups with less socioeconomic heterogeneity, such as poverty-stricken children. The objective of our study was to assess the impact of contextual and individual SEP on dental caries experience among socioeconomically deprived children from Chilean municipalities.

Materials and methods

This report was prepared according to the STROBE recommendations (von Elm *et al.*, 2008). The study population included beneficiaries of a countrywide school dental programme (National Board of School Aid and Scholarships - JUNAEB) obtained from their 2015 electronic register. JUNAEB provides comprehensive, systematic and scheduled dental care to students from kindergarten (4-year-olds) to primary school graduation (14-year-olds). The schools are chosen according to their vulnerability index, calculated by the proportion of students living in poverty and at risk of abandoning the educational system. Thus, beneficiaries include children enrolled in selected schools belonging to middle-to-very-low SEP families. In Chile, 278 out of 346 municipalities throughout the country participate in this dental programme, covering a total of 166,654 children during 2015. The JUNAEB database provided information regarding demographic and socioeconomic individual characteristics as well as DMFT/dmft scores before and after dental treatment registered by non-calibrated dentists delivering the programme nationwide. The contextual variables municipality Human Development Index (HDI) and rurality index were added to the database for this analysis. These variables were obtained from the United Nations Development Program (UNDP) 2014 and the 2017 Census respectively.

Table 1 describes the contextual and individual level variables used in the study following LEVEL recommendations (Monsalves *et al.*, 2020). At the Municipality level, we used the Human Development Index (HDI) to assess contextual SEP. This index, scored from zero to one, aggregates key dimensions of human development: long and healthy life, being knowledgeable and having a decent living standard. The municipality HDI uses local measures of income, health and education obtained from routinely collected data (UNDP, 2014), categorised according to the UNDP classification into a five point ordinal scale from very high to very low (the latter selected as reference category) to allow for comparison with the literature. We also included as a covariate at this level the rurality index for each municipality (i.e., proportion of the municipality population living in rural areas) obtained from the 2017 Census (National Institute of Statistics, 2017).

Table 1. Contextual and individual level variables.

Sub-Index for multilevel mixed equations	*Level*	*Variables*
I	Municipality	Human Development Index (HDI) Rurality Index
J	Child	Gender Living in extreme poverty School grade DMFT dmft

Two individual level outcome variables were selected to measure caries and treatment experience: DMFT for permanent teeth and dmft for primary teeth. Both scores were calculated for children having mixed dentition. All individual variables including DMFT/dmft were recorded using the standardised JUNAEB dental record system.

We classified individual-level SEP as living in extreme poverty, (i.e., individuals earning less than 148 USD monthly according to national calculations) and any other socioeconomic position. The Chilean Ministry of Social Development collects data of families covered by the 'national social protection policy for individuals living in extreme poverty' and provides this information to the JUNAEB database.

We selected two individual-level covariates from the JUNAEB database: gender (male/female) and school grade as a proxy for age. According to the Chilean education system, formal pre-school education is comprised by Pre-kindergarten (four-year-olds) and Kindergarten (five-year-olds); while primary education consists of eight grades for children aged between 6 and 14 years. School attendance in the country is high (98,9%), and the grade retention rate is low (3.6%) (Chilean Ministry of education, 2018); consequently, school grade was considered an appropriate proxy for age and categorised as pre-school children (4-5-year-olds), lower primary education (6-9-year-olds) and upper primary education (10-14-year-olds).

We performed a descriptive analysis on characteristics of the sample. It was hypothesised that individual dental caries experience was dependent on contextual and individual SEP. After assessing their distribution, we observed that both DMFT and dmft scores presented overdispersion and excess of zero counts. Thus, multilevel Poisson, Zero-inflated and Negative Binomial regression models were run and compared to select the type of model to use for the study. We chose multilevel negative binomial models since they were a better fit to the data. Afterwards, we fitted four models for dmft and DMFT to assess the impact of HDI and individual SEP on caries experience and the difference in variance before and after covariates. First, a null model with only DMFT/dmft. Second, a model with the association between HDI and DMFT/dmft. Third, a with the association between HDI (contextual SEP), extreme poverty (individual SEP) and DMFT/dmft; and fourth, a full model adjusted for covariates (age,

gender and rurality). The variance partition coefficient was calculated for full models as suggested by Leckie et al. (2019) Prevalence ratios (PR) with their 95% confidence intervals were calculated. Forest plots were constructed for each outcome under study.

The final model included 5 independent variables with the municipality and individual-specific random effects:

$$Y_{ij} = log[\lambda_{ij}] = [\beta_0 + \beta_{0i}\ ] + \beta_1 HDI_i + \beta_2 rurality\ index_i + \beta_3 Sex_{ij} + \beta_4 living\ in\ extreme\ poverty_{ij} + \beta_5 school\ grade_{ij} + e_{ij}$$

$$Y_{ij} \sim Poisson(\lambda_{ij})$$

where the vector X_i is the vector of municipality-level characteristics and $\beta_{1\text{-}2}$ the vector associated regression coefficients. The vector X_{ij} denotes the individual-level characteristics and $\beta_{3\text{-}5}$ the vector associated regression coefficient. In each model, we assumed that the distribution of the random effects was normal: $\beta_{0i} \sim N(0, \sigma^2_{districts})$ and independent of the model error.

Supplementary analyses further investigated the research question. First, multilevel logistic regression models using caries prevalence as main outcome explored potential differences with our caries experience models. Interactions between contextual (municipality HDI) and individual SEP (extreme poverty), between contextual SEP and rurality and between individual SEP and rurality were tested due to the possibility of individual SEP modifying the effect of contextual SEP on caries and contextual rurality modifying the impact of SEP on children caries experience respectively.

Results

Table 2 displays the distribution of the variables under study. The full sample comprised 161,836 individuals. The multilevel analysis considered only individuals with full records n=112,429 (missing = 30.5%). Most children attended primary school, a third of whom lived in extreme poverty. Mean DMFT was 1.59 while dmft was 2.51. Most children lived in a low or medium HDI municipality, while only a small proportion lived in a very low or high HDI municipality. Municipalities with a very high HDI were not covered by the dental programme and therefore were not considered for the study.

Multilevel models for caries experience are displayed in Table 3. Likelihood ratio tests suggested best goodness of fit of the fully adjusted models for dmft/DMFT. The null model for both outcomes (dmft/DMFT) showed variation at municipality level. The fully adjusted models suggested that caries experience in children with permanent teeth did not differ by municipality HDI (i.e., wide confidence intervals that include value 1).

Children had similar dmft scores across the HDI categories. The only exception was in medium HDI municipalities, where the proportion of children with caries experience was 25% lower in the fully adjusted model. Rurality did not explain differences in caries experience between socioeconomically deprived children living in different municipalities. Municipality-level factors accounted for 9% and 13% of the modelled variation in dmft and DMFT between children living in extreme poverty respectively in the fully adjusted models. On the other hand, individual SEP was associated with caries experience in both dentitions. The proportion of children living in extreme poverty with caries experience in primary teeth was 17% higher than those not living in extreme poverty, and 9% higher for children with permanent teeth, independent of the SEP of their municipality of residence after adjusting for all covariates.

Sensitivity analyses showed similar patterns. When evaluating caries prevalence, no evidence of an association of contextual SEP in deciduous teeth was observed in the fully adjusted model, and a slightly lower likelihood of caries presence of children in low and medium HDI municipalities when compared to very low municipalities. Also, no interactions between contextual and individual SEP, contextual SEP and rurality, and between individual SEP and rurality for any of the outcomes studied (dmft/DMFT) were observed. Furthermore, the lack of an association between contextual SEP and caries experience, and the presence of an association between individual SEP and caries experience remained (all data available on request).

Table 2. Demographic and socioeconomic characteristics of the sample.

Individual-level variables (n_1= 112,429)	*%*
Gender	
Male	49.7
Female	50.3
Living in extreme poverty	
Yes	29.4
No	70.6
School Grade	
Pre-school	18.5
Lower Primary	43.3
Upper Primary	38.2
DMFT, mean (SD[1])	1.59(2.27)
Dmft, mean (SD[1])	2.51(2.73)
Municipality-level variables (n_2=255)	*%*
Human Development Index (Categorised)	
Very Low (0.000-0.349)	2.3
Low (0.350-0.554)	56.1
Medium (0.555- 0.699)	38.2
High (0.700- 0.799)	3.3
Very High (0.800-1.000)	0
Human Development Index (continuous), mean (SD)	0.5(0.1)
Rurality Index, mean (SD)	0.2(0.2)

[1]SD=Standard Deviation

Discussion

This study aimed to assess the relative impact of contextual and individual SEP on dental caries experience among socioeconomically deprived children from Chilean municipalities. Very low and higher HDI municipalities did not predict caries experience in the primary and permanent dentitions among socioeconomically deprived children, except for children in medium SEP municipalities who had lower dmft levels than children from very low HDI. However, children living in extreme poverty had consistently higher caries experience than those who were not extremely poor, independent of their municipality HDI.

Table 3. Multilevel Negative binomial regression model for the association between contextual and individual socioeconomic position and caries experience.

Fixed parameters	*DMFT*		*dmft*	
	'Null' model PR (95% CI)	*Fully adjusted model PR (95% CI)*	*Null' model PR (95% CI)*	*Fully adjusted model PR (95% CI)*
Intercept	1.40 (1.30-1.51)	0.07 (0.03-0.14)	2.34 (2.27-2.53)	3.71 (2.26-6.09)
First Level: individual				
Gender				
Male		Ref.		Ref.
Female		1.15 (1.13-1.16)		0.94 (0.92-0.95)
Age				
Pre-schooler		Ref.		Ref.
Lower Primary		8.11 (7.29-9.03)		1.11 (1.09-1.13)
Upper Primary		29.36 (26.4-32.65)		0.58 (0.57-0.60)
Extreme Poverty				
No		Ref.	Ref.	Ref.
Yes		1.17 (1.15-1.19)	1.09 (1.07-1.10)	1.09 (1.08-1.11)
Second Level: Municipality				
HDI				
Very Low		Ref.	Ref.	Ref.
Low		0.78 (0.56-1.09)	0.80 (0.64-1.00)	0.84 (0.67-1.05)
Medium		0.76 (0.53-1.10)	0.68 (0.53-0.86)	0.75 (0.58-0.97)
High		0.89 (0.42-1.90)	0.76 (0.45-1.27)	0.87 (0.51-1.46)
Rurality Index		1.02 (0.99-1.19)		1.02 (0.99-1.05)
Random Parameters				
Level-2 Variance	1.35	1.19	1.40	0.93
Level-1 Variance	8.44	5.38	11.76	8.55
VPC[1]	0.14	0.13	0.11	0.09

[1]VPC: variance partition coefficient
LRtest: $p<0.001$ for fully-adjusted model when compared to null models for both dmft and DMFT outcomes

The analysis focused on vulnerable children living in lower SEP municipalities, allowing us to explore inequalities in dental status among those at higher risk of disease and the relative effect of individual and contextual SEP. This is important since the effect of contextual SEP varies across different population groups (Schwendicke *et al.*, 2015) and it is necessary to understand the role of social determinants in specific settings to create appropriate local policies to tackle oral health inequalities. Within this sample contextual SEP (i.e., municipality SEP) did not have a strong effect on inequalities in dental caries experience in both dentitions, which differs from results of previous studies where the SEP of the place of residence has been associated to inequalities in oral health. For example, Mathur et al. (2014) compared children living in extreme poverty, poor and middle-class areas of New Delhi observing a clear social gradient. The lack of a contextural social gradient in our study could be due to differences in the methodology as Mathur *et al.* (2014) did not use multilevel modelling. Also, cultural and social norms may differ between countries and influence the impact of contextual SEP on individual oral health. Contextual SEP could have a negative influence on individuals living in highly vulnerable municipalities independent of their individual SEP due to less accessible dental health services, higher prevalence of unhealthy eating habits, lack of adequate recreational spaces, fewer social interactions and lower sense of safety. These characteristics of very low SEP municipalities could lead to worse oral health (Van Meijieren-van Lunteren *et al.*, 2021). However, our analysis did not find statistical differences among deprived children living in municipalities with different SEP, which may be due to equitable access to oral health provided by JUNAEB to the beneficiary schools. Alternatively, our sample comprised children already participating in a national dental programme, thus they are more likely to have state support compared their peers not participating in JUNAEB.

This apparent lack of effect could also be related to individual SEP being a stronger determinant of oral health status than contextual SEP among Chilean children from vulnerable backgrounds. This study found that individual SEP is associated with caries experience independently of municipality SEP among children covered by the dental programme. Squassi et al. (2008) compared children living in extreme poverty vs poor and middle-class children from the same vulnerable neighbourhoods in Buenos Aires. They observed higher DMFS among children with both individual and contextual lower SEP (i.e., extreme-poor children living in a vulnerable neighbourhood) compared to contextual low SEP and higher individual SEP (i.e., non-extreme-poor children from the same neighbourhood). Another explanation could be related to individual differences among children from the

same municipality. The low variance partition coefficient (Table 3) suggested that most variation in DMFT/dmft levels can be attributed to the characteristics of children (first level), thus giving a lower relative importance to Municipality factors such as HDI and rurality (second level) in DMFT/dmft inequalities. However, the apparent lack of effect of contextual SEP may also be because the sample was restricted to children attending schools with high proportions of deprived children.

This study has several strengths. First, we used a representative sample of poverty-stricken children due to the JUNAEB dental programme being present in most municipalities of the country. Second, we focused on the analysis of the effect of contextual and individual SEP on caries experience among vulnerable children, which has not been widely studied. And third, our analysis considered interactions between individual and contextual SEP and between SEP and rurality to observe whether they had an effect on caries experience as part of the process to select the final models.

Among the limitations of this study is the limited applicability of the results to other populations due to the characteristics of the data and its focus on a specific context (vulnerable children participating in JUNAEB programme). This may have restricted the effect of contextual SEP. Another limitation was that this study relied on secondary data sources. The database was extracted from the electronic records of a dental programme where dentists across the country log their oral examinations and treatments, thus, dentists were not calibrated for oral examinations and there was no data quality control system, an effect that tends to be diluted by the high number of records included. This also led to the need of using school grade as a proxy for age as it was the closest variable available, but introduced some variability in children's age. Another limitation is related to the variability in SEP to be expected to exist within municipalities, as individuals from any SEP can live in a given municipality. However, Chile is considered a segregated country, and so, municipality SEP tends to match individual SEP (individuals with similar SEP tend to live in the same municipalities).

Our results suggest that health strategies or policies aimed at vulnerable groups could focus on lower-income children (individual SEP) within all municipalities, regardless of the social position of the municipality (contextual SEP). However, this suggestion should be considered in the specific context of this research (i.e., middle-to-very-low-SEP municipalities only) that restricted the assessment of the overall area level deprivation in the country. Thus, strategies aiming at contextual factors to create healthier environments should also consider the risk of increasing inequalities when only using interventions targeted at individual risk. In this sense, dental programmes such as JUNAEB dental modules, are an opportunity to tackle oral inequalities in both levels by providing oral health promotion and prevention as well as dental treatments to children in vulnerable schools located in low SEP municipalities, since children from deprived areas are far less likely to access regular dental care.

Conclusions

This study assessed the effect of contextual and individual SEP on caries experience among vulnerable children from different Chilean municipalities. The results suggest that individual SEP is a stronger determinant than contextual SEP within this restricted population. These findings could help the development of health strategies focused on individual SEP that allow efficiently reduce oral health inequalities among socioeconomically deprived children.

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