Socio-economic status, psychosocial factors, health behaviours and incidence of dental caries in 12-year-old children living in deprived communities in Manaus, Brazil

Short title: Predictors of dental caries incidence in children

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ABSTRACT

Objectives: This study examines the relationships between socio-economic status, psychosocial factors, health-related behaviours and the incidence of dental caries among 12-year-old schoolchildren living in deprived communities in Manaus, Brazil.

Methods: A longitudinal study involving 312 children aged 12 years was conducted in the city of Manaus, Brazil. Baseline data including socio-economic status (number of goods, household overcrowding, parents' schooling, family income), psychosocial factors (sense of coherence [SOC-13], social support [Social Support Appraisals questionnaire]) and health-related behaviours (frequency of toothbrushing, sugar consumption, sedentary behaviour) were collected through structured questionnaires. The number of decayed teeth was clinically assessed at baseline and one-year follow-up. A hypothesised model evaluating the direct and indirect pathways between the variables was tested using confirmatory factor analysis and structural equation modelling.

Results: The incidence of dental caries at the one-year follow-up was 25.6%. Sugar consumption (β = 0.103) and sedentary behaviour (β = 0.102) directly predicted the incidence of dental caries. A higher socio-economic status was directly linked with lower sugar consumption (β = -0.243) and higher sedentary behaviour (β = 0.227). Higher social support directly predicted lower sugar consumption (β = -0.114). Lower socio-economic status (β = -0.046) and lower social support (β = -0.026) indirectly predicted the incidence of dental caries via sugar consumption and sedentary behaviour.

Conclusions: In the population studied, sugar consumption and sedentary behaviour are meaningful predictors of the incidence of dental caries among schoolchildren living in deprived communities. Indirect pathways of lower socio-economic status and low social support with dental caries incidence via sugar consumption and sedentary behaviour were detected. These findings should be considered in oral interventions and oral health care policies to prevent dental caries among children living in deprivation.

Clinical significance: Social conditions, social support, sedentary behaviour and sugar consumption directly influence dental caries in children.

1. Introduction

Dental caries is a non-communicable chronic disease caused by dental biofilm that induces net mineral loss of dental hard tissues [1]. From a public health point of view, dental caries is one of the most prevalent chronic diseases worldwide and considered a problem of global relevance with significant costs and burdens on individuals and societies [2]. Temporal trends from the early 1970s to mid-1990s, suggest a rapid decline in caries in children from high-income countries. In contrast, lower-income countries exhibit a lower decrease in the reduction of dental caries [3].

The multifactorial causes of dental caries involve biological factors, behaviours, psychosocial factors and environmental determinants [4]. The cariogenic process results from biochemical changes associated with dental biofilm accumulation, which is predominantly composed of fermentable carbohydrates [5]. The onset and progression of caries causally link to the interactions between saliva flow, fluoride and oral microorganisms, however, sugars (e.g. sucrose-containing products) are the key factors due to their cariogenic properties [6]. The importance of sugars in the aetiology of dental caries highlights the relevance of socio-economic characteristics and psychosocial factors to dietary patterns and other health-related behaviours (e.g., fluoridate toothpaste use) [7-9].

Previous systematic reviews examined the evidence for the relationships between socio-economic status, psychosocial factors, screen time, diet and dental caries [10-14]. Overall, their findings suggest that higher socio-economic status [10], protective psychosocial factors (e.g. sense of coherence) [11] and lower frequency of free sugar intake [14] associated with lower levels of dental caries. Higher consumption of sugar also relates to poorer socio-economic conditions [12] and sedentary behaviour [13]. However, the studies included in the reviews occurred in developed countries and in

wealthy regions of developing countries. Information on the predictors of dental caries amongst deprived and underserved populations is relatively scarce. One of the main conclusions shared by the reviews refers to the limited strength of evidence due to the methodological limitations of the primary studies, including the use of a cross-sectional design, which limits causal inference [10-14]. Furthermore, primary studies included in these reviews predominantly adopted regression analysis as statistical method to investigate predictors of dental caries. Therefore, the current understanding of the causal factors of dental caries is limited, because the temporal dynamic relationships between predictors of dental caries, including evaluation of the causal chain (e.g., mediators), changes over time, and the lack of comprehensive examination of the assessment of the incidence of dental caries as outcome measures [10-14].

Theoretical explanations for inequalities in oral health acknowledge the interactions between material, behavioural and psychosocial factors as a complex web of causation [15]. However, previous longitudinal studies predominantly evaluated the above-mentioned theories using subjective oral health outcome measures [16-18]. For instance, the harmful effects of psychological distress and the adoption of health-compromising behaviours mediated the influence of socio-economic status and psychosocial factors on self-perceived oral health in Brazilian adults [17].

Studies investigating the behavioural and psychosocial pathways by which social inequalities may influence dental caries in children should use a longitudinal design and follow-up participants for a reasonable time, evaluate the incidence of dental caries and adopt a theoretical model that simultaneously acknowledges the role of socio-economic background, psychosocial factors and behaviours in the occurrence of dental caries. The following gaps in knowledge prompted us to conduct the present study. First, previous studies did not assess the complex and concomitant associations between socio-economic

status, psychosocial factors, health-related behaviours and dental caries in children. Second, there is little evidence on the predictors of dental caries among people living in deprived communities. Third, few studies have adopted a longitudinal research design to investigate the factors associated with the incidence of dental caries.

This study was conducted in the city of Manaus, Amazonas, Brazil. Manaus is the most populous city in the state with a predominantly urban population, enabling testing the above-mentioned relationships. Manaus had a population of 1,802,525 inhabitants in 2010 and an estimated population of 2,130,264 in the year 2017. Almost all residents (99.5%) live in the urban areas of the city and occupy around 4% of the territorial extension of the city. The Human Development Index (HDI) of Manaus was 0.737 in 2010. There were 447,946 residents in the eastern region in 2010, which was ranked as the second most populous and the most deprived region of the city, according to the Gini Index of 0.440 and an HDI score equal to 0.659.

The aim of this study was to examine the relationships between socio-economic status, psychosocial factors, health-related behaviours and the incidence of dental caries in children living in deprived communities. The theoretical model proposed in Fig. 1 encompasses the relationships between structural and intermediary variables using the World Health Organization (WHO) Conceptual Framework for Action on the Social Determinants of Health [19]. The specific objectives were to evaluate (i) the direct association between health behaviours, including frequency of toothbrushing, frequency of sugar consumption and sedentary behaviour, and the incidence of dental caries, and (ii) the extent to which the above-mentioned behaviours intervene in the influence of socio-economic status, sense of coherence and social support on the incidence of dental caries.

2. Methods

This study uses the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) checklist to improve the quality of reporting.

2.1 Ethical aspects

The present study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of the XXXXX (blinded for peer review, Protocol no. 57273316.1.0000.5020). Researchers informed children and parents about the aims and procedures of the study and the option to opt out. Those who agreed to participate signed the written informed consent authorizing the participation before data collection.

2.2 Study design and population

This was a prospective observational longitudinal study involving children recruited in public schools in the eastern region of the city of Manaus, Brazil.

2.3 Sampling process and eligibility criteria

The study sample comprised of 12-year-old children enrolled in year 7 of public schools in the 11 neighbourhoods of the eastern region of the city of Manaus. The study employed a two-stage random sampling process to select participants. Of the 104 public schools in the eastern region, 36 schools with students in year 7 were initially identified. Of these, a proportional selection of 25 schools represented the population of 12-year-old students across the neighbourhoods of the region. Schools with more students were therefore more likely to be selected. All 12-year-old students from all year 7 classrooms at the selected schools were invited to participate. The study excluded children undergoing orthodontic treatment with fixed appliances, and those with syndromes, such as craniofacial

anomalies, or requiring special care dentistry, including those with severe physical or intellectual disabilities.

Assuming that the minimum effect size estimated through structural equation modelling with two latent variables and five observed variables involving 312 subjects was at least 0.18, with a 5% Type I error probability, the power of the present study is estimated as at least 80% [20].

2.4 Theoretical model

The theoretical model hypothesized the relationships between adjacent and non-adjacent variables using the WHO Conceptual Framework for Action on the Social Determinants of Health [19]. According to this model, the determinants of the incidence of dental caries are organized across structural and intermediary determinants. The former considered socio-economic status assessed through number of goods, overcrowded accommodation, parents' schooling and family income. The intermediary determinants considered two dimensions: psychosocial factors (sense of coherence and social support) and behaviours (frequency of toothbrushing, sugar consumption and sedentary behaviours) (Fig. 1). The study postulated that mechanisms by which structural and intermediary determinants influence dental caries occur through adjacent levels. For instance, higher socio-economic status, a greater sense of coherence, greater social support, greater frequency of toothbrushing, lower sugar consumption and lower levels of sedentary behaviour directly predict a lower incidence of dental caries. Furthermore, socio-economic status and psychosocial factors predict dental caries through psychosocial factors and health-related behaviours. The latter would also mediate the association between psychosocial factors and dental caries.

2.5 Data collection

Data were obtained through self-administered questionnaires and clinical oral examinations in a private room at the school premises. Initially, participants received detailed instructions on how to respond to the structured questionnaires. Next, they completed the questionnaires evaluating psychosocial factors and health-related behaviours under researcher supervision (see online Appendix 1). Researchers provided clarification about the items of the questionnaire on request. Parents of children provided information on socio-economic status, including number of goods, overcrowded accommodation, parents' schooling and family income, through a questionnaire (see online Appendix 1). Baseline data collection was conducted from September to December 2016.

Dental caries was assessed at baseline and at one-year follow-up by five calibrated dentists using a plain dental mirror No 5 (Duflex®) and the WHO ball-point probe. Dentists carried out dental examinations on school chairs, under natural light and without drying the teeth, in specific rooms defined by administrative staff at the schools in accordance with the WHO guidelines for oral health surveys [21]. Participants conducted oral hygiene under supervision of a dentist before the clinical oral examinations.

2.6 Dental caries assessment

Dental caries was evaluated in the permanent teeth at baseline and at one-year follow-up according to the number of teeth with untreated caries into dentine (D3 threshold) using the Decayed, Missed, Filled Tooth (DMFT) index [21]. For each participant, every tooth evaluated as decayed (code 1) and restored with caries (code 2) were recoded as '1' and summed to obtain the number of teeth with untreated dental caries into the dentine. Healthy teeth (code 0), filled teeth without caries (code 3), missing teeth (codes 4 and 5)

and teeth with sealants (code 6) were recoded as '0'. Each tooth coded as '0' at baseline and coded as '1' at one-year follow-up was considered as a new decayed tooth. The outcome of the study was the incidence of dental caries according to the number of new decayed teeth. The rationale for a one-year interval for the assessment of dental caries incidence is because participants are at higher risk of developing new caries lesions in the short term because they were from deprived communities, with a high prevalence of dental caries (28.8%) at baseline, which are well-known predictors of dental caries.

2.7 Socio-economic status

Socio-economic status was a latent variable using the following indicators: number of goods, house overcrowding, parents' schooling and monthly family income. Number of goods was measured according to a list of 11 durable goods at home (e.g. television, refrigerator, washing machine, dishwasher machine). Calculating overcrowded accommodation occurred by dividing the number of residents by the number of the rooms in the house (1 = 0–1.99, 2 = 2–2.99, 3 = ≥ 3). Parents' schooling was measured according to the total number of years of schooling with approval (1 = 1–7, 2 = 8–11, 3 = ≥ 12). Monthly family income was registered in Brazilian minimal wages (BMW) as follows: 1 = ≤ ½ BMW, 2 = ½ to 1 BMW, 3 = > 1 BMW. One BMW corresponded to US$271.09 in 2016 [22].

2.8 Psychosocial factors

Sense of coherence was assessed using the cross-culturally adapted version of the SOC-13 scale for Brazilian children [23,24]. The 13 items of the SOC-13 were assessed using a five-point Likert scale. The sense of coherence score was obtained by summing up the scores of the 13 items after inverting the scores of the items contrary to a sense of

coherence. A higher SOC-13 score indicates a greater sense of coherence. Social support was a latent variable measured by the dimensions of the Social Support Appraisals (SSA) questionnaire [25], using the valid version for the Brazilian population [26]. The 30-item SSA questionnaire used a six-point Likert scale comprising the dimensions of 'family', 'friends', 'teachers' and 'others'. The response options were: 1 = 'fully agree', 2 = 'strongly agree', 3 = 'agree a little', 4 = 'somewhat disagree', 5 = 'strongly disagree', 6 = 'fully disagree'. A sum of scores obtained total score of social support for the items. The higher the SSA score, the greater the level of social support.

2.9 Health-related behaviours

Health-related behaviours were frequency of toothbrushing, sugar consumption and sedentary behaviour. Frequency of toothbrushing was assessed based on the question used in the National School-Based Health Survey (*Pesquisa Nacional de Saúde do Escolar – PeNSE*) [27]: 'How many times a day do you brush your teeth?' (1 = up to two times a day, 2 = three or more times a day). Daily sugar consumption was measured using the Food Frequency Questionnaire (FFQ), which is composed of a checklist of 14 groups of cariogenic foods and beverages [28,29]. Colourful pictures facilitated children's understandings of real-size food portions and drinks. A 10-point scale assessed each item of daily intake of cariogenic foods and beverages, based on the frequency of intake and amount consumed. The question used in the *PeNSE* survey assessed sedentary behaviour [27]: 'In an ordinary weekday, how many hours a day do you spend in watching TV, using computer and video games or doing other sitting activities?' (1 = < 1 hour per day, 2 = 1 to 2 hours per day, 3 = 3 to 4 hours per day, 4 = > 4 hours per day).

2.10 Clinical calibration and questionnaire reliability

A clinical calibration study carried out involved 10 children aged 12 years before the main study; selection of these children occurred in a public school and data excluded from the main study. A one-week interval between clinical examinations assessed intra-examiner reliability for the DMFT index. Use of the completed questionnaires confirmed understanding of the items. The inter- and intra-examiner Kappa coefficients for the DMFT at baseline ranged from 0.91 to 0.98 and from 0.80 to 0.81, respectively. The Kappa coefficients for the DMFT at the one-year follow-up ranged from 0.73 to 0.86 for inter-examiner agreement and from 0.86 to 0.95 for intra-examiner agreement.

The clinical examinations and questionnaires were replicated with 10% of the participants to evaluate temporal reliability using the Kappa coefficient and intraclass correlation coefficient (ICC), respectively. The intra-examiner Kappa coefficient was 0.93 for the DMFT, and the ICCs of agreement for sense of coherence, social support and daily sugar consumption were 0.89, 0.89 and 0.72, respectively. Cronbach's alpha coefficient, assessing the internal consistency of the sense of coherence, social support and daily sugar consumption were 0.67, 0.88 and 0.75, respectively.

2.11 Data analysis

Reporting of descriptive data of socio-economic status, psychosocial factors, health-related behaviours and dental caries used means, standard errors and proportions. Initially, the dependence of observations (children) across the primary sampling units (schools) was analysed due to the two-stage sample design. The likelihood test was used to compare Akaike's information criterion (AIC) between the null model with the school-level variable (AIC = 255.14) and without the school-level variable (AIC = 253.14), estimated using Poisson regression. There were no significant differences in the number of new decayed teeth between schools (p-value = 0.157). Therefore, it was assumed the

variance of the incidence of dental caries between schools was not significant and multilevel analysis accounting for clustering was not used.

The measurement model was tested by confirmatory factor analysis to assess the multidimensionality of socio-economic status, social support latent variables and correspondence with the proposed indicators. Structural equation modelling, using the maximum likelihood estimation method, examined the total, direct and indirect relationships between the observed and latent variables according to the theoretical model, using SPSS AMOS 24.0. The total effects estimates represent the sum of the direct and indirect effects. The former represents a direct path from one variable to another, while the latter refers to a path mediated through other variables. The significance of the indirect effects was employed to evaluate mediation using bias-corrected bootstrap confidence intervals with a 900 resampling from the original data set, in order to derive less biased standard errors and 95% confidence intervals [30]. Non-significant paths were removed from the full model to generate a statistically parsimonious model.

The chi-squared test (χ^2/df) was used to assess the adequacy of the overall fit of the measurement, complete and parsimonious models. Other fit indices were also used, such as the goodness of fit index (GFI), the comparative fit index (CFI), the standardized root mean square residual (SRMR) and the root mean square error of approximation (RMSEA), which are indicators for the closeness of fit. The threshold considered for a good model fit was χ^2/df < 3.0, a SRMR < 0.08, a RMSEA < 0.06 and GFI and CFI values > 0.90 [31].

3. Results

Initially, 528 eligible students aged 12 years were identified. Of these, 86 did not return the consent form or their parents did not agree to their participation (response rate =

83.7%). A further 27 children were excluded due to orthodontic appliances, resulting in 415 participants at baseline. Of these, 56 children were lost at the one-year follow-up (retention rate equal to 86.5%), and 47 children were excluded because the number of decayed teeth with cavities decreased due to dental treatment during the study period (e.g. dental restorations and dental extractions). Thus, the final analytical sample consisted of 312 children.

Of the 312 children, 80 (25.6%) had one or more new carious lesions at the one-year follow-up. Participants' socio-economic status characteristics, psychosocial factors, health-related behaviours and clinical measures are presented in Table 1. The majority of the children were girls (56.4%) and from families with a monthly family income of between half the BMW and one BMW (41.3%). Social support and sense of coherence mean scores were 141.87 (SE = 0.95) and 45.88 (SE = 0.37), respectively. Most participants brushed their teeth three or more times per day (63.5%) and spent two hours or less per day in sedentary activities (66.7%). The mean of the DMFT and the mean of the number of decayed teeth had increased by 51.7% and 38.3%, respectively, between baseline and one-year follow-up.

Confirmatory factor analysis supported the measurement model composed of two latent variables, namely socio-economic status and social support (see online Appendix 2). The items confirming the latent variable socio-economic status were number of goods (β = 0.499), overcrowded accommodation (β = 0.348), parents' schooling (β = 0.257) and family income (β = 0.532). The items that confirmed the variable social support were the SSA dimensions of social support from friends (β = 0.735), relatives (β = 0.658), teachers (β = 0.558) and others (β = 0.828).

Structural equation modelling indicated that the theoretical model (full model) was an acceptable fit for the data. The measurement, complete and parsimonious models indicated satisfactory fit indices, meeting all the a priori criteria (see online Appendix 3).

The non-significant hypothesised paths in the theoretical model were removed and the model was re-estimated to generate a parsimonious model. The full and parsimonious models did not differ statistically when compared using the chi-squared test ($\Delta\chi^2 = 0.122$, df $= 7$, p-value > 0.05), suggesting the removed pathways were not relevant to the model.

Higher socio-economic status directly predicted lower sugar consumption ($\beta = -0.243$) and more sedentary behaviour ($\beta = 0.227$). Lower sugar consumption was directly predicted by greater social support ($\beta = -0.114$). A greater sense of coherence was linked to greater frequency of toothbrushing ($\beta = 0.148$). The incidence of dental caries was directly predicted by higher sugar consumption ($\beta = 0.103$) and more sedentary behaviour ($\beta = 0.102$). Significant indirect effects between variables were also identified. Lower socio-economic status was indirectly linked with sugar consumption via sedentary behaviour ($\beta = 0.026$). Incidence of dental caries was indirectly predicted by lower socio-economic status ($\beta = -0.046$) and lower social support ($\beta = -0.026$). Sedentarism was indirectly linked with incidence of dental caries via high sugar consumption ($\beta = 0.012$) (Figure 2 and Appendix 4).

4. Discussion

The present longitudinal study supports the hypothesis that lower socio-economic status, psychosocial factors and unhealthy behaviours are meaningful predictors for incidence of dental caries in 12-year-old children living in deprivation over a one-year period. A theoretical model was used to investigate simultaneous associations as well as to test the direct and indirect pathways between variables using structural equation modelling [30].

Children from a lower socio-economic status, with lower social support, higher sugar consumption and more sedentary behaviour were at higher risk of new dental caries lesions over a one-year period. Indirect effects indicated that sugar consumption mediated the association of socio-economic status and social support with incidence of dental caries. In addition, socio-economic status was indirectly linked to the incidence of dental caries via sedentary behaviour.

Epidemiologic research on the determinants of dental caries focuses on the influence of the nature and persistence of socio-economic circumstances during childhood and the occurrence of dental caries in adulthood [32]. The association of socio-economic status, psychosocial factors and health-related behaviours with the prevalence of dental caries in children and adolescents has been assessed in cross-sectional studies [33-38]. Yet, there are few studies on how these factors operate to affect dental caries. Therefore, the present findings provide a better understanding of the mechanisms that explain the relationship between lower socio-economic status and the incidence of dental caries.

To date, few cross-sectional studies have assessed the possible pathways between the predictors of dental caries [36-38]. Recent research has reported the mediating effect of unhealthy food on the relationship of lower socio-economic status and sedentary behaviours with dental caries prevalence in adolescents [36-38]. In addition, toothbrushing frequency mediated the link of socio-economic status [36,38] and unhealthy food [37] with dental caries. Psychosocial factors, including social support and a sense of coherence, are associated with dental caries experience through sugar intake and toothbrushing frequency [36]. The present study adds to the evidence base in that it demonstrates the causal chain involving socio-economic status, psychosocial factors and unhealthy behaviours related to the incidence of dental caries among children living in

deprived communities. According to our findings, sugar consumption and sedentarism are the mediators by which socio-economic status influences the incidence of dental caries, this supports the behavioural explanation of social inequalities in oral health [15]. In addition, the present results endorse the critiques of the emphasis placed on the behavioural risks to dental diseases, because adverse social conditions increase the likelihood of higher sugar consumption [39].

The importance of socio-economic inequalities as a relevant determinant of oral health behaviours among Brazilian adolescents has been described [40]. The association between lower socio-economic status and higher frequency of sugar consumption observed in the present study may be explained by the fact that children from low-income families are at higher risk of food insecurity, which in turn correlates with dental caries and hunger [41]. Our findings also indicate the direct relationship between higher socio-economic status and sedentary behaviour. These findings are in accordance with data from a birth cohort in Brazil demonstrating that low-income children exhibit higher levels of physical activity than those from higher income groups [42]. Nonetheless, previous results of a large cross-national survey involving schoolchildren in North America and Europe suggest that children's sedentary behaviour is lower among those from higher socio-economic status [43]. The possible influence of family socio-economic status on sedentarism in children may depend on a country's characteristics, such as cultural norms and national policies and guidelines to promote physical activity among children.

According to our findings, sedentary behaviour predicts greater consumption of sugar and incidence of dental caries. In addition, sugar consumption mediates the link between sedentary behaviour and dental caries incidence. Previous research has concluded that television viewing time predicts daily consumption of sweets and soft drinks amongst schoolchildren and dental caries in children and adolescents [43,44]. It

has also been suggested that marketing strategies used in television advertisements expose children to messages that promote the consumption of unhealthy foods and drinks [44]. As far as the authors are aware, this is the first study revealing the interrelationships between socio-economic status, sedentarism, sugar consumption and the incidence of dental caries. The lack of association between toothbrushing frequency and the incidence of dental caries was an unexpected finding, explained by the duration of the study, because a one-year follow-up period might be insufficient to detect the influence of high frequency of toothbrushing on the prevention of new dental caries. In addition, greater frequency of toothbrushing may not necessarily result in more effective removal of dental biofilm.

Children with higher social support were at lower risk of dental caries over the one-year period via lower consumption of sugar. Pooled estimates from longitudinal studies indicate that greater levels of social support are associated with lower levels of caries in adolescents [11]. However, the mechanisms by which social support may reduce the risk of dental caries are poorly understood. Social support can produce oral health benefits by reducing psychological distress and social isolation, preventing engagement in health-threatening behaviours, such as sugar consumption [45]. Therefore, our findings suggest that social support may act as a protective factor for the incidence of dental caries through the engagement in health-promoting behaviours.

The present study addresses an underexplored topic in dental research, namely there is a paucity of evidence on relationships between socio-economic indicators, psychosocial factors, health-related behaviours and the incidence of dental caries amongst underprivileged children. The strengths of this study include its longitudinal design, the adoption of a theoretical model to guide the selection of variables and to hypothesize the relationships between them and the use of a representative random sample. In addition,

structural equation modelling is a robust analytical method enabling assessment of the direct and indirect effects between variables, as well as confirmation that the model was a good fit for the data.

Limitations of the study are that recruitment of the studied sample derived from public schools in a socially deprived area of the city. Therefore, our findings may not be applicable to children from different socio-economic backgrounds. Other potential predictors of dental caries in children were not evaluated in this study, such as family-level characteristics (e.g. parenting style and family composition), access to dental care and use of fluoride, which should be investigated in future research.

The strengths of this study were the longitudinal design, the use of a population-based sample of children, and the incidence of dental caries as study outcome. In addition, the study adopted structural equation modelling, which is considered a robust statistical method to examine direct and indirect relationships between variables.

5. Conclusion

The present findings suggest that oral health behaviours are proximal causes of dental caries. Lower socio-economic status and lower social support may increase the risk of new dental caries, mediated by sugar consumption and sedentary behaviour, in the population studied. This study therefore indicates that population strategies aimed at tackling dental caries should be embedded into general public health policies, such as those focusing on common risk factors, as well as actions to reduce social inequalities. The reduction of sedentarism among children and adolescents through the encouragement of physical activity, television advertisement regulations and the enhancement of a healthy diet should be included in the policy agenda of oral health professionals. Similarly, dental professionals should advocate for public policies focusing on the

reduction of social inequalities, as these measures have a great potential to improve children's oral health.

Competing Interests

The authors declare no potential conflicts of interests with respect to the authorship and/or publication of this article.

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Table 1. Socio-economic status, psychosocial factors, oral health-related behaviours and dental caries measures (N = 312).

Variables	Total sample
Sex, N (%)	
Male	136 (43.6)
Female	176 (56.4)
Socio-economic status	
Number of goods, Mean (SE)	6.63 (0.15)
Overcrowded accommodation N (%)	
0 to 1.99	218 (69.9)
2 to 2.9941.3	65 (20.8)
3 or more	29 (9.3)
Parents' schooling, N (%)	
1 to 7 years	54 (17.3)
8 to 11 years	220 (70.5)
12 or more years	38 (12.2)
Family Income, N (%)	
$\leq$ ½ BMW	77 (24.7)
½ to 1 BMW	129 (41.3)
> 1 BMW	106 (34.0)
Psychosocial Factors	
Social Support, Mean (SE)	
Total score	141.87 (0.95)
Family	42.22 (0.30)
Friends	33.15 (0.33)
Teachers	29.77 (0.30)
Others	36.73 (0.31)
Sense of Coherence, Mean (SE)	45.88 (0.37)
Health-related behaviour	
Frequency of toothbrushing, N (%)	
Up to 2 times a day	114 (36.5)
3 or more times a day	198 (63.5)
Daily sugar consumption, Mean (SE)	4.30 (0.22)
Sedentary Behaviour, N (%)	
< 1 hour per day	108 (34.6)
1 to 2 hours per day	100 (32.1)
3 to 4 hours per day	49 (15.7)
> 4 hours per day	55 (17.6)
Dental caries, Mean (SE)	
Decayed teeth at baseline	0.60 (0.07)
Decayed teeth at one-year follow-up	0.91 (0.08)
DMFT at baseline	1.20 (0.10)
DMFT at one-year follow-up	1.66 (0.11)

BMW Brazilian minimum wage

Figure 1. Theoretical model of the relationships of structural and intermediate determinants with dental caries incidence, adapted from the model of the Commission on Social Determinants of Health (WHO, 2010).
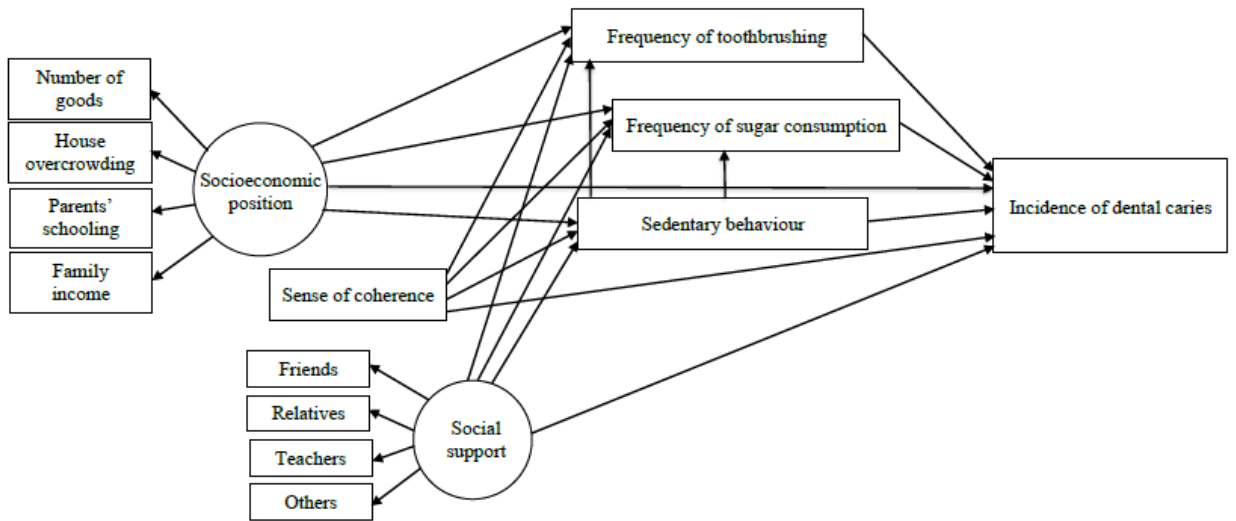
Figure 2. Direct (solid lies) and indirect (dashed lines) effects (bootstrapped standardized estimates) for the final statistically parsimonious model.
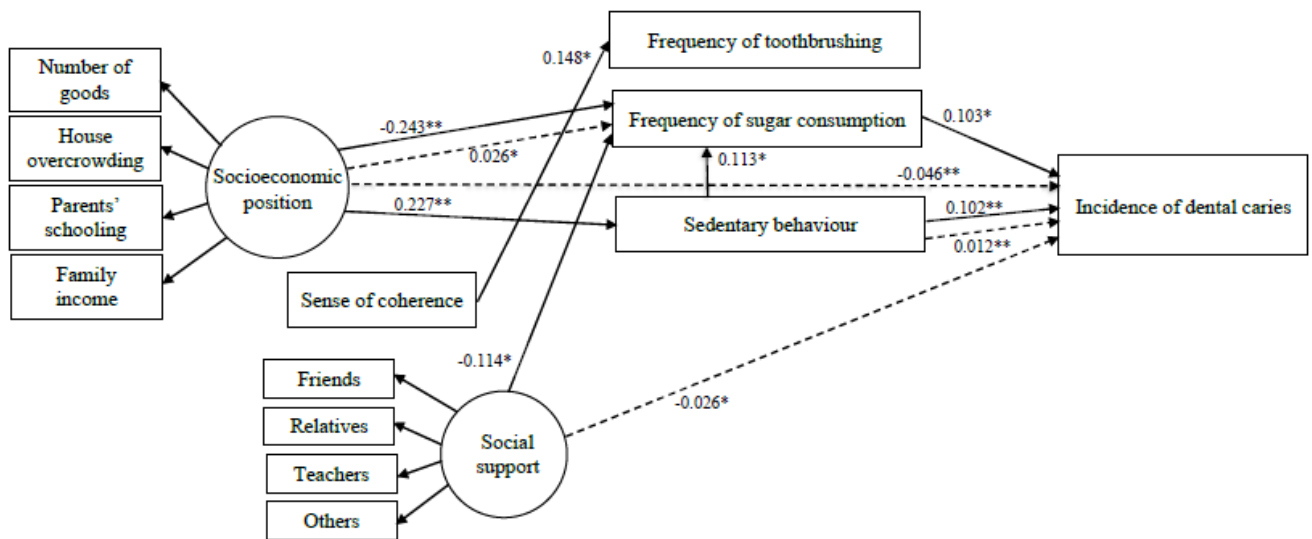
Footnote Figure 3: For Bootstrapped SE/ BC 95% CI, see Appendix 1. *$P < 0.05$, * $P < 0.01$.

Appendix 1. Socio-economic status, psychosocial factors and health-related behaviours questionnaires.

Original versions of the questionnaires were in Portuguese language. The English versions of the questionnaires are also presented.

Portuguese version

Status Socioeconômico

Quantos bens têm em sua residência? *Considerar como bens: televisão, geladeria, aparelho de som, micro-ondas, telefone, telefone celular, máquina de lavar roupa, máquina de lavar louça, microcomputador e número de carros.* *Varia de 0 a 11 bens. (somente o carro pode ser contado duas vezes)*	|_____|
Quantas pessoas moram em sua casa?	|_____|
Quantos cômodos têm em sua casa?	|_____|
Quantos cômodos estão servindo permanentemente de dormitório para os moradores deste domicílio?	|_____|

No mês passado, quanto receberam, em reais, juntas, todas as pessoas que moram na sua casa incluindo salários, bolsa família, pensão, aluguel, aposentadoria ou outros rendimentos?
    1. Até 1/2 salário mínimo (Até R$440,00)
    2. Mais que 1/2 salário mínimo até 1 salário mínimo(de R$ 441,00 a R$880,00)
    3. Mais que 1 salário mínimo até 2 salários mínimos (de R$ 881,00 a R$1.760,00)
    4. Mais que 2 salários mínimos até 5 salários mínimos (de R$ 1.761,00 a R$4.400,00)
    5. Mais que 5 salários mínimos até 10 salários mínimos (de R$4.401,00 a R$ 8.800,00)
    6. Mais que 10 salarios mínimos (mais que R$ 8.801,00)
	|_____|

O(a) senhor(a) estudou?	|___| Sim	|___| Não

Se estudou, escreva até que série ou anos completos com aprovação que o(a) senhor(a) estudou.* ____série do 1º. grau/ensino fundamental ____série do 2º. grau/ensino médio ____anos completos de estudo do ensino superior/faculdade * A resposta foi transformada em anos de estudo	|_____|

Fatores psicossociais

Senso de coerência (SOC-13 scale)

Instruções: Aqui estão 13 perguntas sobre vários aspectos da sua vida. Cada pergunta tem cinco respostas possíveis. Marque com um X a opção que melhor expresse a sua maneira de pensar e sentir em relação ao que está sendo falado. Dê apenas uma única resposta em cada pergunta, por favor.

	Um enorme sofrimento e aborrecimento	Um sofrimento e aborrecimento	Nem aborrecimento nem satisfação	Um prazer e satisfação	Um enorme prazer e satisfação
Aquilo que você faz diariamente é:					
	Sem nenhum objetivo	Com poucos objetivos	Com alguns objetivos	Com muitos objetivos	Repleta de objetivos
Até hoje a sua vida tem sido:					
	Nunca	Poucas vezes	Algumas vezes	Muitas vezes	Sempre
Você tem interesse pelo que se passa ao seu redor?					
Você acha que você é tratada com injustiça?					
Você tem ideias e sentimentos confusos?					
Você acha que as coisas que você faz na sua vida têm pouco sentido?					
Já lhe aconteceu ter ficado desapontada com pessoas em quem					
Você tem sentimentos que gostaria de não ter?					
Você tem dúvida se pode controlar seus sentimentos?					
Já lhe aconteceu de ficar surpreendida com o comportamento de pessoas que você achava que					
Em algumas situações, as pessoas sentem-se fracassadas. Você já se					
Você sente que está numa situação pouco comum, e sem saber o que					
	Totalmente errada	Errada	Nem correta e nem errada	Correta	Totalmente correta
Às vezes acontecem coisas na vida da gente que depois achamos que não demos a devida importância. Quando alguma coisa acontece na sua vida, você acaba achando que deu a importância:					

Apoio social (Social Support Appraisals)

"Agora vamos falar sobre sua relação familiar, amigos e participação em grupos comunitários"
Não existe certo ou errado. É importante responder do jeito que você se sente agora.

1. Concordo totalmente   2. Concordo bastante   3. Concordo um pouco   4. Discordo um pouco
5. Discordo bastante   6. Discordo totalmente

Os meus amigos me respeitam	
Tenho professores que se preocupam bastante comigo	
Eu sou bastante querido pela minha família	
Eu não sou importante para os outros	
Os meus professores gostam de mim	
A minha família se preocupa bastante comigo	
As pessoas de um modo geral, gostam de mim	
De maneira geral, posso confiar nos meus amigos	
Sou bastante admirado pelos meus familiares	
Sou respeitado pelas pessoas em geral	
Meus amigos não se preocupam nada comigo	
Meus professores me admiram bastante	
Eu sou querido pelas pessoas	
Eu me sinto muito ligado aos meus amigos	
Os meus professores confiam em mim	
A minha família gosta muito de mim	
Os meus amigos gostam de estar comigo	
No geral, não posso contar com meus professores para me darem apoio	
As pessoas da minha família confiam em mim	
Sinto que as pessoas, de um modo geral, me admiram	
A maioria dos meus professores me respeita muito	
Não posso contar com a minha família para me dar apoio	
Eu me sinto bem quando estou com outras pessoas	
Eu e os meus amigos somos muito importantes uns para os outros	
A minha família me respeita muito	
Sinto que as pessoas me dão valor	
Eu ajudo os meus amigos e eles me ajudam	
Não me sinto muito ligado aos meus professores	
Se eu morresse amanhã poucas pessoas sentiriam saudades de mim	
Não me sinto muito ligado à minha família	

Comportamentos relacionados à saúde

Frequência de escovação dentária

Normalmente, quantas vezes por dia você escova os dentes?	Até duas vezes ao dia |___|	Três ou mais vezes ao dia |___|

Consumo de açúcar

Agora vamos falar sobre a sua alimentação. Para nós é importante saber como tem sido a sua alimentação no último ano. Vou listar alguns alimentos e peço que você me diga se comeu esses alimentos, quantas vezes e a quantidade.

Alimento	Comeu alguma vez?	Com que frequência?	Quantas vezes?	Porção média	Porção Menos	igual	mais
Açúcar que você coloca no café/ leite, suco ou frutas (branco/marrom)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	3 colheres de chá	|__|	|__|	|__|
Achocolatado (Toddynho,Nescau)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 unidade	|__|	|__|	|__|
Refrigerante/chá industrializado/ suco de caixa ou pó	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 copo	|__|	|__|	|__|
Chocolate em pó (Nescau, Toddy)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	2 colheres de sopa	|__|	|__|	|__|
Guloseimas (bala, bombom),caramelo/toffee/ pirulito/chiclete)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	4 unidades	|__|	|__|	|__|
Doce de colher (por exemplo: geléia e doce de cupuaçu)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	3 colheres de sopa	|__|	|__|	|__|
Sobremesas doces (goiabada, marmelada,coca-da,quebra-queixo,pudim)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 fatia pequena/ 2 colheres de sopa	|__|	|__|	|__|
Docinhos de festa (Brigadeiro, beijinho,olho de sogra)	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 unidade	|__|	|__|	|__|
Chocolate em barra	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 barra pequena ou 1 bombom	|__|	|__|	|__|
Biscoito doce/bolacha recheada	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	5 unidades	|__|	|__|	|__|
Bolo/pão doce/sonho	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 fatia grande/ 1 unidade	|__|	|__|	|__|
Pipoca doce/amendoim doce/pipoca com leite condensado	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	1 saco/ 1 pacote	|__|	|__|	|__|
Sorvete/picolé/ din-din	|___|Não |___|Sim	|__|D |__|S |__|M|__|A	1 2 3 4 5 6 7 8 9 10	2 bolas/1 unidade	|__|	|__|	|__|

Legenda: D = dia S = semana M = mês A = ano

Comportamento sedentário

Em um dia de semana comum, quantas horas por dia você fica sentado (a), assistindo televisão, usando o computador, jogando videogame, ou fazendo outras atividades sentado (a)?	Até 1 hora por dia |___|	De 1 a 2 horas por dia |___|	3 a 4 horas por dia |___|	Mais de 4 horas por dia |___|

Socio-economic status

How many goods do you have in your household? Consider as goods: TV, refrigerator, stereo, microwave, telephone, cell phone, washing machine, dishwasher, computer and number of cars. It can range from 0 to 11 goods. (only the car can be counted twice)	|__|
How many people live in your house?	|__|
How many rooms do you have in your house?	|__|
How many rooms are permanently being used as dormitories for the residents of this household?	|__|

Last month, how much did all the people who live in your house receive, in reais, together, including wages, family allowance, pension, rent, retirement or other income?
  1. Up to 1/2 minimum wage (Up to R$440.00)
  2. More than 1/2 minimum wage up to 1 minimum wage (from BRL 441.00 to BRL 880.00)
  3. More than 1 minimum wage up to 2 minimum wages (from BRL 881.00 to BRL 1,760.00)
  4. More than 2 minimum wages up to 5 minimum wages (from BRL 1,761.00 to BRL 4,400.00)
  5. More than 5 minimum wages up to 10 minimum wages (from R$4,401.00 to R$8,800.00)
  6. More than 10 minimum wages (more than BRL 8,801.00)
	|__|

Have you study? 1|__| Yes	2|__| No
If you studied, choose which series or completed years with approval that you studied. ____ series of the 1st. grade/elementary school ____ series of the 2nd. grade/high school ____full years of higher education/college study The answer was converted into years of study	|__|

Psychosocial factors questionnaires

Sense of coherence (SOC-13 scale)

Instructions: Here are 13 questions about various aspects of your life. Each question has five possible answers. Mark with an X the option that best expresses your way of thinking and feeling about what is being said. Give only one answer to each question, please.

	A source of pain and boredom				A source of deep pleasure and satisfaction
Doing the things you do every day is:					
	With no purpose	With few goals	With some goals	With many goals	Full of goals
So far your life has been:					
	Never	Very seldom	Sometimes	Very often	Always
Do you have the feeling that you don't really care about what goes on around you?					
Do you have the feeling that you're being treated unfairly?					
Do you have very mixed-up feelings and ideas?					
Do you have the feeling that there's little meaning in the things you do in your daily life?					
Have you ever been disappointed in people you trusted?					
Does it happen that you have feelings inside that you would rather not feel?					
Do you have feelings that you're not sure you can keep your feeling under control?					
Have you ever been surprised by the behaviour of people you thought you knew well?					
People feel losers in certain situations. Have you ever felt like a failure?					
Do you feel that you are in an unusual situation, and not knowing what to do?					
	Completely wrong	Incorrect	Neither correct nor	Correct	Fully correct
Sometimes things happen in people's lives that later we think we didn't give due importance. When something happens in your life, you end up thinking you gave the importance:					

Social Support (Social Support Appraisals)

"Below are a list of statements about your relationships with family and friends. Please, indicate how much you agree or disagree with each statement as being true.
There is no right or wrong answer. It is important to answer the way you are felling now.

1. Fully agree   2. Strongly Agree   3. Agree a little   4. Somewhat disagree
5. Strongly disagree   6. Fully disagree

My friends respect me	
My teachers care for me very much	
I am loved dearly by my family	
I am not important to others	
I am loved dearly by my teachers	
My family cares for me very much	
I am well liked	
I can rely on my friends	
I am really admired by my family	
I am respected by other people	
My friends don't care about my welfare	
I am really admired by my teachers	
I am held in high esteem	
I feel a strong bond with my friends	
My teachers rely on me	
My family cares for me very much	
My friends look out for me	
I can't rely on teachers for support	
My family rely on me	
I am really admired by people	
I am respected by my teachers	
I can't rely on my family for support	
I feel well with other people	
My friends and I are really important to each other	
My family really respect me	
I feel valued by other people	
My friends and I have done a lot for one another	
I don't fell close to my teachers	
If I die tomorrow, very few people would miss me	
I don't feel close to members of my family	

Health-related behaviours

Frequency of toothbrushing

How many times a day do you brush your teeth?	Up to two times a day |___|	Three or more times a day |___|

Sugar consumption

Now let's talk about your food. It is important for us to know how your diet has been in the last year. I will list some foods and ask you to tell me if you ate these foods, how many times and the amount

Food	Have you ever eaten?	How often?	How many times?	Medium Portion	Portion		
					Less	equal	more
Sugar you put in coffee/milk, juice or fruit (white/brown)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	3 teaspoons	|__|	|__|	|__|
Chocolate powder (Toddynho, Nescau)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 unit	|__|	|__|	|__|
Soda/industrialized tea/ boxed juice or powder	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 glass	|__|	|__|	|__|
Chocolate powder (Nescau, Toddy)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	2 soup spoons	|__|	|__|	|__|
Sweets (candy, bonbon), caramel/toffee/lollipop/gum)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	4 units	|__|	|__|	|__|
Spoon candy (for example: jelly and cupuaçu candy)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	3 soup spoons	|__|	|__|	|__|
Sweet desserts (guava paste, marmalade, coke, pudding)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 small slice / 2 tablespoons	|__|	|__|	|__|
Party sweets (Brigadeiro)	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 unity	|__|	|__|	|__|
Chocolate bar	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 small bar or 1 bonbon	|__|	|__|	|__|
Sweet biscuit/Stuffed biscuit	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	5 unities	|__|	|__|	|__|
Cake/sweet bread	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 big slice/ 1 unit	|__|	|__|	|__|
Sweet popcorn/sweet peanuts/popcorn with condensed milk	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	1 bag/ 1 package	|__|	|__|	|__|
Ice cream/popsicle	|___| No |___| Yes	|__|D |__|W|__|M|__|Y	1 2 3 4 5 6 7 8 9 10	2 scoops/1 unity	|__|	|__|	|__|

Legenda: D = day W = week M = month Y = year

Sedentary behaviour

In an ordinary weekday, how many hours a day do you spend in watching TV, using computer and video games or doing other sitting activities?	< 1 hour per day |___|	1 to 2 hours per day |___|	3 to 4 hours per day |___|	More than 4 hours per day |___|

Appendix 2. Confirmatory factor analysis of two factors and eight items observed in the measurement model, obtained by bootstrap loading (standard error/bias-corrected 95% CI). *$P < 0.05$, **$P < 0.01$.
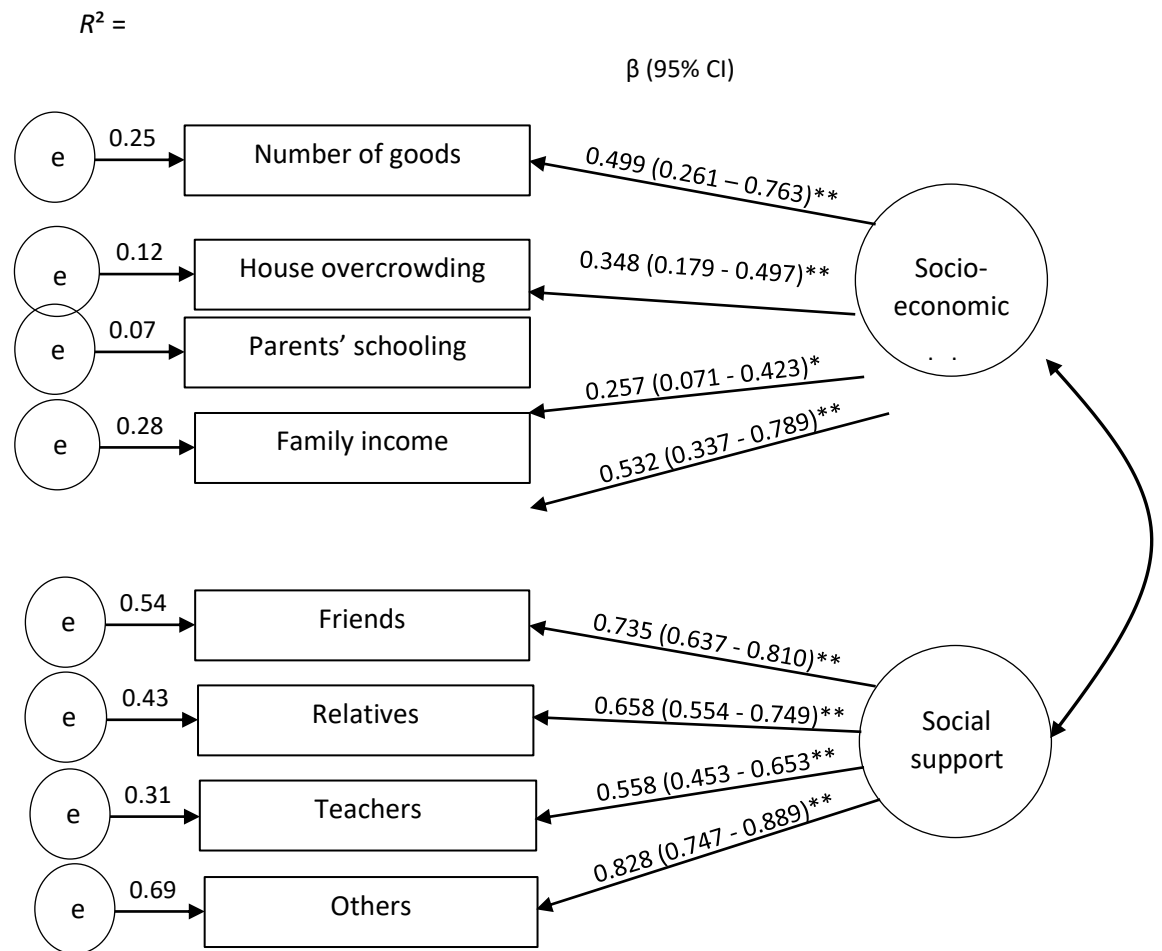
Appendix 3. Fit indices for the confirmatory factor analysis of measurement, full and parsimonious models.

Model	X²(df)	GFI	CFI	SRMR	RMSEA
Measurement model	0.509	0.993	1.00	0.029	0.000
Full	1.718	0.960	0.928	0.043	0.048
Parsimonious	1.596	0.957	0.932	0.047	0.044

Measurement model: confirmatory factor analysis between latent variables (socioeconomic position and social support). Model Full: Theoretical model. Parsimonious model: Relationships between socio-economic status, psychosocial factors, health-related behaviours and dental caries incidence with multiple direct and indirect effects model with pathways between all adjacent and non-adjacent levels
$\chi 2/df$ ratio: Chi square and degrees of freedom ratio, GFI: Goodness of fit statistics; CFI: comparative fit index, SRMR: standardized root mean- squared residual, RMSEA: root-mean-square error of approximation.

Appendix 4. Direct and indirect effects of the parsimonious model.

Effects	β	Bootstrap SE	95% CI
Direct Effects			
Socio-economic status – Sugar consumption	-0.243	0.089	-0.400 / -0.063**
Socio-economic status – Sedentary behaviour	0.227	0.088	0.041 / 0.401**
Sense of coherence – Frequency of toothbrushing	0.148	0.066	0.005 / 0.269*
Social support – Sugar consumption	-0.114	0.007	-0.128 / -0.100*
Sedentary behaviour – Sugar consumption	0.113	0.058	0.001 / 0.223**
Sedentary behaviour – Dental caries incidence	0.102	0.052	0.002 / 0.204**
Sugar consumption – Dental caries incidence	0.103	0.057	0.001 / 0.214**
Sense of coherence – Frequency of toothbrushing	0.148	0.066	0.005 / 0.269**
Indirect Effects	β	Bootstrap SE	95% CI
Socio-economic status – Sugar consumption	0.026	0.020	0.001 / 0.078**
Socio-economic status – Dental caries incidence	-0.046	0.023	-0.101 / -0.010*
Social support – Dental caries incidence	-0.026	0.015	-0.068 / -0.006*
Sedentary behaviour – Dental caries incidence	0.012	0.009	0.001 / 0.037**

β = bootstrapped standardised estimate; SE =Standard error; CI = confidence interval; *P < 0.05; **P < 0.01