


Socio-economic inequality in oral health in childhood to young adulthood, despite full dental coverage

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The aim of this cross-sectional study was to assess differences in caries experience according to socio-economic status (SES) in a health-care system with full coverage of dental costs for children up to the age of 18 yr. In 2011 and 2014, by performing hurdle negative binomial models, we obtained data on 3,022 children and young adults aged 5, 8, 11, 14, 17, 20, and 23 yr, living in four cities in the Netherlands. At all ages between 5 and 23 yr, the percentages of children with caries-free dentitions were lower and mean caries experience were higher in low-SES than in high-SES participants. In 5-yr-old children with dmft > 0, mean caries experience was 3.6 in those with low SES and 2.3 in those with high SES. In 23-yr-old participants, these estimates were 6.8 and 4.4, respectively ($P < 0.05$). Low-SES children have a greater risk of more caries experience than high-SES children. Thus, in a system with full free paediatric dental coverage, socio-economic inequality in caries experience still exists. Dental health professionals, well-child care doctors and nurses, general practitioners, and elementary school teachers should collaborate to promote oral health at the community level, with specific targeting of low-SES families. We further need policy measures to curtail, at community level, the increasing availability and consumption of highly processed, carbohydrate-rich foods, with particular attention for low-SES families.

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Disparities in child health according to socio-economic status (SES) are often reported. Youths in high-SES families generally experience better health than youths in low-SES families (1). Children and young adolescents experiencing socio-economic disadvantages encounter a wide range of health risk factors and adverse outcomes in adulthood (2), including increased risks of injury, asthma, and elevated blood pressure, as well as involvement in risky health behaviours, such as smoking and physical inactivity (2, 3).

Dental caries experience is reportedly a strong indicator of socio-economic inequality in both children and adults (4–11). It is the most common paediatric disease (12). Among 5- to 17-yr-old individuals in the USA, dental caries is over five times more common than asthma and seven times more common than hay fever (13). The term ‘dental caries’ refers to decay on any surface of a tooth (14). It is characterized by a continuum of disease states, ranging from subclinical lesions to cavitated lesions that extend into dentine or even into the pulp. If left untreated, caries may lead to pain, discomfort, infections, or tooth loss. Dental caries, and poor oral health in general, has a major impact on children’s overall health, growth, and development. It not only affects the ability to chew and eat properly but

can also result in lost school hours and affect a child’s overall wellness and self-esteem (15, 16).

Prevention of caries in children requires adequate oral hygiene and a healthy diet with limited cariogenic foods, as well as starting young with dental check-ups and regular dental visits. Risk factors, on the other hand, include brushing teeth less than two times a day, frequent consumption of cariogenic foods, skipping breakfast, and lower parental educational level and income (12, 17–20). Low-SES individuals have been found to be more likely to have inadequate preventive oral-health behaviour (21, 22).

Availability of full financial coverage for costs of dental care may also affect whether children receive dental care and the occurrence of dental caries (23). However, other factors may contribute, such as low parental oral health literacy and limited parental language proficiency (23, 24). Moreover, care-related barriers may add to this (e.g. inadequate preventive services, care that is not culturally well adapted, and services that do not fully take into account low levels of oral health literacy) (23, 24).

In the Netherlands, dental care for youth is included in the mandatory health insurance and is free of charge for children up to 18 yr of age. Research in this setting

can clarify to which degree factors other than the costs of dental care contribute to socio-economic differences in caries experience. The research question for this study was therefore: In a health-care system with full coverage of dental costs for children up to the age of 18 yr, does a socio-economic difference in caries experience exist, based on SES? Our hypothesis was that between socio-economic groups in children up to 18 yr of age, all of whom have free access to dental services, no differences in oral health would exist.

Material and methods

Study population

During the study period from March 2011 through October 2011 and April 2014 through November 2014, children and young adults aged 5–23 yr who were living in four medium-sized cities in the Netherlands were eligible to participate. These four cities (Gouda, Alphen aan den Rijn, Breda, and Den Bosch) are typical of the Dutch population regarding age, gender, ethnicity, and marital status (25). Random samples were drawn from the municipal population records of each city and stratified according to age, to reach similar numbers per city per age category. Sample sizes were determined based on the potential to detect relative differences of 30% in mean caries experience, from earlier estimates from 2005 to 2009, at an alpha of 0.05 with a power of 80%. This led to a required sample size of about 450 children per age category (26, 27).

In total, 13,961 children and young adults aged 5–23 yr (and their parents) received invitations to participate, including information about the purpose of the study. Trained interviewers personally attempted to contact individuals who had not responded, to emphasize the importance of the study. If the initial contact attempt failed, the interviewer made a maximum of three additional attempts. Individuals who refused to participate were asked to fill out a non-response questionnaire with questions about gender, SES, and oral health behaviour. Of the 13,961 children and young adults and their parents invited to take part in the study, 3,022 (23%) participated.

Ethics statement

The Central Committee on Research Involving Human Subjects concluded that no ethical considerations were involved, as the clinical proceedings were harmless and the questions not sensitive in nature. The study met all the requirements of the Personal Data Protection Act (number m1383077 for 2011 and number m1556571 for 2014).

Procedure and measures

Data were gathered via clinical oral examinations and a questionnaire. The questionnaire was completed by a parent for the 5-, 8-, and 11-yr-old children and by the 14-, 17-, 20-, and 23-yr-old subjects themselves. In this study, SES was operationalized as the highest level of education completed by the mother of the children aged 5, 8, and 11 yr or by the adolescent/young adult (ages 14, 17, 20, and 23 yr). A total of 10 or fewer years of education was coded as low SES, whereas a total of more than 10 yr of

education was coded as high SES. This decision was in accordance with the International Standard Classification for Education 2011 (28).

The total score of the decayed, missing, and restored teeth (DMFT) index was used to indicate level of caries experience (29). The DMFT score represents caries experience in permanent teeth, whereas the dmft score represents that in deciduous teeth. Caries-free dentitions are defined in our paper as those with dmft = 0 or DMFT = 0. Caries experience was observed during a clinical oral examination that comprised visual inspection of the teeth with documentation of caries lesions and any subsequent treatment (i.e. restoration or extraction). Participants in urgent need of treatment were advised to visit their dental professional.

Clinical examinations were performed by four dentists in a mobile oral health facility. During the clinical assessment, both permanent and deciduous teeth were evaluated, depending on the age of the participant. For children aged 5 yr, only caries in deciduous teeth was included. For children aged 8 yr, caries in both deciduous and permanent teeth was included. For children aged 11 yr or older, permanent teeth were evaluated, with the exclusion of wisdom teeth.

To assess the quality of the clinical examinations, we determined the inter-examiner agreement for 304 participants in 2011 and 137 participants in 2014. We calculated overall Pearson correlations and intraclass correlations between the two examiners, and mean outcomes of each examiner for dmft and DMFT. The intraclass correlation coefficients were 0.92 and 0.95, respectively. Differences between the two examiners in mean caries experience were clinically negligible (i.e. at most 0.2 dmft and DMFT).

Data analysis

First, we calculated descriptive statistics for gender, SES, ethnicity, toothbrushing frequency, and dental attendance for the 5-, 8-, 11-, 14-, 17-, 20-, and 23-yr-old participants in the sample. Second, we assessed mean caries experience for low-SES and high-SES children. We used Student's *t*-tests or Mann–Whitney *U*-tests to assess statistical significance, depending on the frequency distribution. Crosstabs and chi-square tests were used for categorical variables. Third, we assessed differences in caries experience according to SES and age, using hurdle modelling. Hurdle models have the advantage of estimating two separate parameters to accommodate many zero counts: one estimate for the dichotomization of zero vs. non-zero (i.e. caries-free or not); and one estimate for caries experience in cases of not-caries-free. As the count part had a negative binomial distribution, we used a negative binomial hurdle model (30). Hurdle analyses yield ORs for the probability of having any caries and, in the case of those with caries, rate ratios comparing the greater caries experience of low-SES groups with that of high-SES groups (30). We made one hurdle model for caries experience in the deciduous teeth and another for caries experience in the permanent teeth. Models were adjusted for age and age-squared because the relationship between age and caries experience for the count part was not linear. We performed bivariate analyses using spss, version 22.0 (IBM, Armonk, NY, USA), and negative binomial hurdle models in R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

Results

Table 1 shows the characteristics of the participants. Of all participants, 46% were male and 39% had a low SES.

Table 2 shows caries experience in deciduous and permanent teeth and mean caries experience according to age and SES. For all age groups, except 11-yr-old children, the percentage of subjects with caries-free teeth was lower for those with low SES than for those with high SES ($P < 0.05$). We observed mean dmft (or DMFT) scores to be higher in low-SES children than in high-SES children.

Table 3 shows ORs and rate ratios (RRs) for the association of SES and age with caries experience in children aged 5 and 8 yr and children aged 14 yr and older. Children with low-SES had higher odds of dmft > 0 or DMFT > 0 than children with high SES. Low-SES children with dmft > 0 or DMFT > 0 had (on average) more caries experience than did children with high SES, teens, and young adults. The odds of dmft > 0 or DMFT > 0 increased with age. The same held for the mean number of caries experiences. Older children had higher odds of dmft > 0 or DMFT > 0 than did younger children. Older children with dmft > 0 or DMFT > 0 had more caries experience than did younger children. We found no statistically significant interaction of SES with age.

Discussion

At all ages between 5 and 23 yr, children with low SES were less likely to have caries-free teeth and had, on average, more caries experiences. The absolute difference in caries experience between those with low SES and those with high SES was greatest among 23-yr-old subjects. Children with low SES and older children had higher odds for dmft > 0 or DMFT > 0 than children with high SES and younger children. Also, when

having caries, children with low SES and older children had, on average, more caries experiences than did children with high SES and younger children, respectively.

We found a difference in caries experience, according to SES, in a health-care system with full coverage of dental costs for children up to the age of 18 yr. Epidemiological research in the Netherlands reported dental check-up rates of around 95% for children with low SES and high SES from ages 4 to 16 yr (31). Moreover, in our sample, we also found that most participants in all age groups visited dental professionals yearly. Nevertheless, socio-economic differences in caries experience existed, which may be explained in several ways: by client-related factors; by professional-related factors; or by the organization of care.

With respect to client-related factors, children from low-SES groups have been shown to have a greater risk of unfavourable preventive oral health behaviour than their high-SES counterparts, resulting in the gradient found in caries experience (21, 22, 32–34). Low-SES households consume larger quantities of highly processed carbohydrate-rich foods (because such foods are inexpensive) than do high-SES households (35). There is a lack of regulation in the production, availability, and pricing of junk food and sugar-sweetened beverages. Another client-related factor is that parents with low SES may have lower oral health literacy than parents with high SES and consequently have limited potential to teach their children how to perform optimal dental care. In the matter of professional-related factors, not all dental professionals may have the skills to promote oral health behaviour effectively among parents with low SES, or to solve the challenges associated with lower levels of oral health literacy (36, 37). Concerning factors related to the organization of care, clear guidelines for oral health promotion and prevention are not yet available. Without guidelines, dental professionals may be insufficiently informed about the recommendations to train parents how to keep their children's teeth healthy and children to keep their own teeth healthy, and the methods to achieve this.

Our findings of differences in caries experience between participants with low SES and high SES are in line with those of studies completed in Switzerland, Brazil, Denmark, Australia, Los Angeles County (USA), Norway, and southern China (4–8, 10, 11, 38). These findings indicate the socio-economic inequality in oral health in children in multiple countries, despite different dental-coverage systems.

In a Dutch system with full dental coverage, we found inequalities in caries experience according to SES in participants from the ages of 5 yr through 23 yr. In Denmark, socio-economic inequality was still found to exist in dental health, even though almost all children and adolescents attended a free public dental service (6). Moreover, according to DARMAWIKARTA *et al.* (39), among urban Canadian children who had been to a dentist, those in low-income families were more likely to have dental caries. Findings from a study conducted in North Carolina showed that low-income children with extended dental coverage had less dental caries

Table 1

Characteristics of participants according to age category

Variable	Age category (yr)						
	5	8	11	14	17	20	23
	<i>n</i>						
	302	363	453	619	434	438	413
Characteristics							
Male gender	54.9	54.0	49.8	46.5	43.3	39.3	35.7
Low socio-economic status	40.3	38.8	40.8	41.0	38.8	34.7	36.9
Mother with Dutch ethnicity	83.1	87.8	88.9	85.0	82.4	85.3	83.7
Oral health behaviour							
Toothbrushing twice daily	73.9	85.4	82.1	80.6	71.3	73.3	72.6
Dental check-up every 6 months	78.2	87.1	89.7	84.0	82.9	67.1	65.6

Values are given as %.

Table 2

Percentages of Dutch children and young adults with caries experience in deciduous or permanent teeth, and mean caries experience (SD) of them, according to age and SES (2011–2014).

Variable	Age category (yrs) and tooth type							
	5 ^a	8 ^b	11	14	17	20	23	
	<i>n</i>							
	295	363	448	619	420	438	401	
dmft > 0 or DMFT > 0 (%)								
Low SES	42.9*	56.7*	25.5*	21.3	53.5*	66.9*	75.0*	89.2*
High SES	29.5	48.6	13.5	18.9	38.1	52.9	70.3	77.9
Mean caries experience (SD) when dmft > 0 or DMFT > 0								
Low SES	3.6 (2.6)*	4.3 (2.6)*	1.7 (0.8)	2.0 (1.2)	3.3 (2.8)*	4.1 (3.6)	5.4 (4.3)*	6.8 (5.4)*
High SES	2.3 (1.7)	3.1 (2.1)	1.8 (0.9)	1.7 (1.1)	2.3 (1.6)	3.3 (2.6)	4.4 (3.9)	4.4 (3.2)

^aIn this age group, caries experience in the 20 deciduous teeth only.
^bIn this age group, caries experience in deciduous and permanent teeth as present.
 *Statistically significant different from high SES group ($P < 0.05$).

Table 3

Association of socio-economic status (SES) and age with caries experience in deciduous and permanent teeth of children (5 and 8 yr of age) and young adults (14 yr of age and older): findings of Hurdle models

Variable	Deciduous teeth		Permanent teeth [†]	
	OR for dmft > 0 (95% CI)	RR for caries experience (95% CI)	OR for DMFT > 0 (95% CI)	RR for caries experience (95% CI)
SES (Low vs. High)	1.66 (1.13–2.14)**	1.55 (1.32–2.08)***	1.75 (1.41–2.16)***	1.47 (1.29–1.68)***
Centred age (per yr)	1.15 (1.14–1.51)***	1.31 (1.02–1.29)*	1.22 (1.18–1.27)***	1.11 (1.08–1.15)***
Centred age ^{2†}			1.00 (0.98–1.01)	0.99 (0.98–1.00)*
Centred age × SES	0.93 (0.74–1.14)	0.92 (0.79–1.09)	0.99 (0.93–1.06)	1.01 (0.97–1.04)

Age squared was significant, meaning that the association between age and caries experience for the count part was not linear. Therefore age-squared was used in the count model for a better fit.

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

[†]We included a quadratic term for centred age to achieve a better fit of the data with the model. RR, rate ratio.

experience than children in Medicaid (40). These findings indicate that although free dental services are important

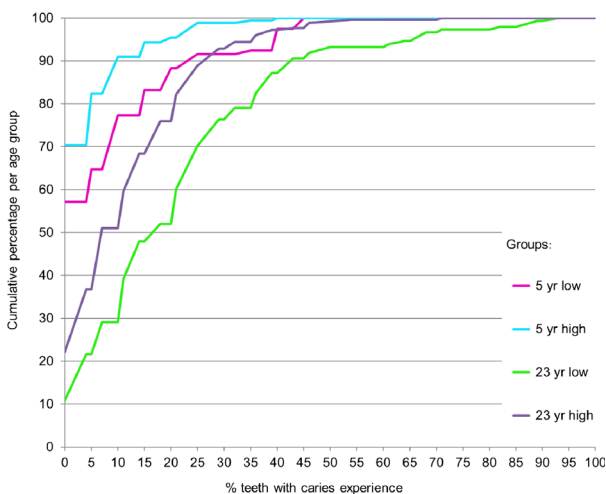


Fig. 1. Cumulative frequency distribution of the percentage of teeth with caries. One-hundred percent teeth with caries experience is equivalent to 20 teeth with caries experience for age 5 yr, and 28 teeth with caries experience for age 23 yr.

for children, socio-economic differences in caries experience may persist nonetheless (Fig. 1).

The findings of this study should be considered in light of its strengths and limitations. The strengths include the large sample of children and young adults shown to be representative of the Dutch population of 5- to 23-yr-old subjects with respect to background variables (26, 41). Moreover, the dental examinations were carried out by trained professionals with satisfactory interexaminer agreement. There are also some limitations. Given the low response rate of 23%, selection bias may have affected our findings. In our study, the inclusion of participants stopped when the required number was reached, slightly increasing non-response rates but less likely causing bias. Non-response analyses indicated why people were unwilling to participate. The most frequent reasons were lack of interest, lack of time, and anxiety, with (in particular) the last item in this list potentially resulting in bias. Moreover, selection bias is less likely as the demographic characteristics of the sample were very similar to those of the general population. A second limitation may be that we assessed SES only according to educational level and not by using other measures, such as income or occupation. Asking about educational level has the advantage of a high response, particularly in

contrast to asking about income; moreover, in the Netherlands, educational level has been found to be the most sensitive indicator of SES (42).

Our finding, of large absolute differences according to SES in all age groups in a country with a system of full dental coverage, suggests a need for additional preventive efforts. The disease of dental caries is preventable (43). One way to prevent it is to change unfavourable oral health behaviours, such as tooth-brushing less than twice daily and frequent consumption of cariogenic food and drinks. Interventions to reach children to prevent caries experience may include enhancing oral health literacy, as well as improving parental knowledge, skills, and self-efficacy in relation to preventive oral health behaviour, both early in life and thereafter.

In this study, differences in mean caries experience between children with low SES and high SES were already present in 5-yr-old participants, despite full dental coverage. One could hypothesize that children receive preventive dental care too late. To minimize socio-economic differences, community-based interventions aimed at improving the oral health of children and young adults should start early in life – as early as the age of 6 months when the first tooth erupts (44, 45). To reach all children, better integration of preventive dental care in well-child care, paediatric primary care, and elementary school programmes could improve caries prevention.

Another challenge to decrease the socio-economic gap is the growing problem of a higher intake of highly processed foods with added sugars in low-SES households, mainly because these low-quality foods are more affordable (35). The cariogenic and obesogenic environment is especially a problem in areas of high deprivation. Better regulation policies for production, pricing, and provision of highly processed foods with fermentable carbohydrates are needed. Furthermore, dental health professionals, well-child care doctors and nurses, and general practitioners should collaborate at community level to motivate parents to favour healthy food choices. Such community-level interventions are, for instance, integrated preventive dental care performed by dental hygienists at well-child clinics or routine referral of children to a dental clinic by a well-child clinic paediatrician. Both interventions are now researched for (cost-)effectiveness in the Netherlands. Dental professionals participating in these interventions follow the Non-Operative Caries Treatment Program while caring for children's teeth (46, 47).

In conclusion, low SES is associated with a lower prevalence of caries-free teeth and more caries experience at the ages of 5–23 yr, even in a system with full dental coverage. The presence of additional socio-economic differences indicate that factors other than access contribute to these differences. Low-SES children may be at a higher risk of unfavourable preventive oral health behaviour than their high-SES counterparts. Dental professionals may not have the skills to promote oral health behaviour effectively, often with challenges for lower levels of oral health literacy. Furthermore, there is a

dearth of clear guidelines for preventive dental care in children. Community-based interventions to decrease the socio-economic differences and to improve oral health may include enhancing oral health literacy and improving parental knowledge, skills, and self-efficacy in relation to preventive oral-health behaviour. Better collaboration between paediatric primary care, elementary schools, and preventive dental care may help motivate parents to brush their child's teeth twice a day, to let their child drink water, and to limit their child's consumption of highly processed carbohydrate-rich foods. Moreover, we need policy measures to curtail, at community level, the increasing availability and consumption of highly processed, carbohydrate-rich foods, which particularly affects low-SES families. Further research is needed on the effectiveness of such interventions and on the degree to which they reach low-SES children. This may reduce child dental morbidity in a major way.

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