Community Dent Oral Epidemiol 2010; 38: 1–9

Community Dentistry and Oral Epidemiology

Socioeconomic factors in adolescents' oral health: are they mediated by oral hygiene behaviors or preventive interventions?

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Polk DE, Weyant RJ, Manz MC. Socioeconomic factors in adolescents' oral health: are they mediated by oral hygiene behaviors or preventive interventions? Community Dent Oral Epidemiol 2010; 38: 1–9. © 2009 John Wiley & Sons A/S

Abstract – *Objectives:* To determine whether there is a socioeconomic status (SES) disparity in caries experience (i.e., DMFT) in an adolescent sample from Pennsylvania and to determine whether differences in oral hygiene behaviors and preventive interventions account for this disparity. *Methods:* A cross-sectional clinical assessment was conducted on a representative sample of 9th grade and 11th grade students across Pennsylvania. These students also completed a brief questionnaire regarding their oral hygiene behaviors. From this group of students, a random subsample of 530 parents completed a questionnaire assessing SES, fluoride exposure, and recency of receipt of dental services. DMFT was examined at two thresholds of severity: simple prevalence (DMFT > 0) and severe caries (DMFT > 3). *Results:* Using structural equation modeling, we found that lower SES was associated with higher prevalence of DMFT and higher prevalence of severe caries. Although lower SES was associated with lower rates of brushing, less use of sealants, and less recent receipt of dental services, these oral health behaviors and preventive interventions did not account for the disparities in DMFT defined by SES. *Conclusions:* There is an SES gradient in caries experience in adolescents in Pennsylvania. Disparities in caries experience, however, cannot be accounted for by SES-associated differences in brushing, flossing, sealant use, fluoride exposure, or recency of use of dental services. To facilitate the design of preventive interventions, future research should determine the pathways through which SES-associated disparities occur.

Key words: adolescent; dental caries; oral hygiene behavior; socioeconomic factors

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Submitted 5 December 2008; accepted 5 August 2009

On a population basis, many diseases demonstrate a strong association with socioeconomic status (SES) such that those higher in social status experience better health. This is such a robust finding across so many diseases that the Institute of Medicine (1) declared social factors to be 'critical determinants of health' and emphasized the importance of including them in planning interventions.

Across a range of health behaviors (2) and health outcomes (3) in adolescents, however, the evidence for a disparity due to SES is mixed, possibly due to changing relationships between health behaviors and SES as the peer group intensifies its pressure to conform (4–6). With respect to caries in adolescents, previous studies have found an SES disparity in unmet treatment needs [e.g. (7)]. However, in a review of studies between 1990 and 1999 (8), there

doi: 10.1111/j.1600-0528.2009.00499.x

was limited information to address whether SES is a risk factor for caries experience, and the evidence across the few studies that did address this question was mixed. Although subsequent studies from several countries have found evidence of an SES disparity in caries experience in adolescents [e.g. (9–12)], some have not [e.g. (13)]. Few studies have addressed this issue in the United States. This represents a gap in our understanding of this issue.

If there is an SES disparity in adolescent caries experience, SES-related differences in the practice of oral hygiene behaviors and use of preventive interventions may be important to examine, as there is abundant evidence demonstrating that both the practice of oral hygiene behaviors and the use of preventive interventions are important in caries development. Caries levels are associated with factors such as tooth brushing (14), fluoride exposure (15, 16), and receipt of sealants (17). Compared with children without untreated caries, children with untreated caries are less likely to obtain regular dental treatment (18). Thus, SES-associated differences in oral hygiene behaviors and use of preventive interventions may account for an SES disparity should one exist. Yet, the degree to which these factors account for an SES disparity in caries experience in adolescents remains unknown.

The purpose of the present study is to determine whether there is an SES disparity in caries experience (i.e., DMFT) in an adolescent sample from Pennsylvania and to determine whether differences in oral hygiene behaviors or preventive interventions can account for this disparity. Identifying the sources of caries disparities in adolescents has important implications for disparities prevention and treatment efforts, which should be targeted as effectively as possible. Specifically, we hypothesized that adolescents' caries levels would be higher among those lower in SES. Additionally, we hypothesized that this disparity would be at least partially accounted for by differences in the following oral hygiene behaviors and preventive interventions: brushing frequency, flossing frequency, use of fluoridated toothpaste and fluoride drops, consumption of fluoridated water, receipt of dental sealants, and recency of receipt of dental services.

Methods

This study uses data collected as part of the Pennsylvania Oral Health Needs Assessment (PaOHNA), which concluded data collection in May 2000. The PaOHNA was a state-wide, school-based screening survey. As is typical for surveys such as these, basic information about children's oral health was obtained to guide state-level policy and planning. In addition to the basic screening evaluation, we also collected limited information about oral health behaviors and family factors. The PaOHNA collected data on a sample of 6040 public school children in grades 1, 3, 9, and 11. The study design was cross-sectional. The sample design for the PaOHNA was a multi-stage probability proportional to size selection of school districts from the public school system of Pennsylvania. There were 13 district-level refusals among the 60 districts initially selected for an initial school district response rate of 78%. Also, there were nine individual schools that refused within districts that had other participating schools, for an initial school participation rate of 94%. To ensure that the sample remained representative for the entire state (i.e. all sampling intervals), replacements were chosen by random probability proportional to size selection of a district or school from the sampling interval for each refusing district or school. Finally, due primarily to nonresponse at the child level within selected schools, the final sample size was 6040 out of the projected target of 7500, for a final response rate of 80.5%. Thus, these children provided a representative sample of Pennsylvania's public schoolchildren in the indicated grades. Details of the sampling methodology have been reported elsewhere (19).

This study is limited to a subset of the 1138 9th grade and 1113 11th grade (adolescent) participants. From this group of 9th and 11th grade students, 530 families were systematically sub-sampled from the larger study population, with the same implicit stratification and clustering characteristics as the schoolchildren screening survey. For this sub-sampled group, a primary caregiver of each child received a 50-item telephone-administered (parent) questionnaire. Thus, the results reported in this paper are based on 530 parent–child pairs.

Institutional Review Board approval was obtained from the University of Pittsburgh prior to initiation of this study. The parent or guardian of each child selected for the study provided consent prior to study participation.

Clinical assessment

Each adolescent received a clinical assessment by a licensed dental hygienist using portable dental equipment in the selected schools. Details of the training and calibration of examiners and of the clinical protocols have been reported elsewhere (19). Strict infection control guidelines recommended by CDC (Bloodborne Pathogens Standard), OSHA, and the American Dental Association were followed and observed at all times. Parents were given a report of findings via the school nurse, and referrals for dental care were provided when needed.

Each tooth was assessed for caries, restorations, and dental sealants. This assessment was done visually with the aid of a mouth mirror, tongue blade, and artificial illumination (either headlamp or dental exam light). Although the teeth were not air dried, they were wiped with gauze. Explorers were not used. Each permanent tooth was classified as sound, filled, carious, or missing based on a modified version of the NHANES III criteria (20, 21). A tooth was classified as carious if on a smooth surface there was visual evidence of cavitation (i.e., a break in the enamel surface) or if on the occlusal surface there was evidence of cavitation or undermined enamel, which included frosting or shadowing of the enamel. To be classified as filled, teeth needed to have evidence of either a permanent or temporary filling. Filled teeth that also contained caries were classified as carious. The sound category was used for teeth with no evidence on any surface of treated or untreated caries and could include teeth with slight staining in an otherwise sound fissure. When permanent teeth were missing, the reason was solicited by the examiner and teeth were classified as missing due to caries, trauma, orthodontics, or other. Third molars were not included in this study. Sealants were marked as present or not present at the child level (0 = absent, 1 = present).

For each child, the numbers of decayed (D), missing (M), and filled (F) teeth were determined. These were summed to create the DMFT index. Because DMFT was not distributed normally, for analysis we created the following two level categorical variables: simple prevalence (DMFT > 0) and severe caries (DMFT > 3). We selected 4 as our cut-off because children with a DMFT > 3 were above the 75th percentile for our sample (9, 11, 22).

Adolescent questionnaire

Each adolescent completed a 12-item questionnaire related to his or her oral hygiene behaviors and perceived oral health status at the time of his or her dental examination. Tooth brushing frequency was categorized as less than once per day, once per day, twice per day, more than twice per day.

Parent questionnaire

The 50-item parent questionnaire assessed SES (family income, educational attainment of both parents), dental insurance, utilization of dental services, difficulties with access to care, parents' oral health status and history of dental treatment, parent's perceived need for treatment for their child, parent's perception of their child's oral health status, parent's concerns over their child's oral health status, and child's exposure to preventive modalities such as fluoridated water, fluoride supplements, and fluoride toothpaste. Parents also reported on their child's flossing and recency of dental service utilization. All questions reported in the current report were closed-ended, and the interviewers were trained and calibrated in the interview. Annual family income was categorized as < \$20 000; \$20 000–\$50 000; \$50 001–\$100 000, or > \$100 000. To control for household size, the median of each category of annual family income (using \$150 000 for > \$100 000) was divided by household size. Parent education was determined by taking the highest educational attainment achieved by either parent and was categorized as less than high school; high school graduate; some college; college graduate; any graduate school.

For flossing, we used less than once or twice per week to define the lower flossing group (0 = infrequent flossing, 1 = frequent flossing). The evidence for flossing efficacy in caries control is lacking, but less than once or twice a week would suggest a very low flossing behavior and likely would not be associated with any caries prevention benefit. For recency of dental utilization, we made the division at having a dental visit more than 1 year ago versus within the past year (0 = >1 year, 1 = within 1 year). For fluoridated water, we combined information from parental self-report regarding whether their water was fluoridated with information regarding whether they filtered their water. Only water that was reported to be both fluoridated and not filtered was considered to be fluoridated. This variable was treated as a categorical variable (0 = No, 1 = Yes). Whether the child's toothpaste was fluoridated and whether the child ever took a fluoride supplement were treated as categorical variables (0 = No, 1 = Yes). Because only seven participants reported that their toothpaste was not fluoridated, information about toothpaste fluoridation was not combined with information about tooth brushing frequency.

Data entry and statistical analysis

All data were entered into laptop computers running EPI INFO database software either at the time of the clinical screening examinations via direct data entry or later from paper collection forms. After the data were checked for accuracy, they were transferred to SAS 9.1 (SAS Institute, Cary, NC, USA) and Mplus 5.1 (Muthén and Muthén, Los Angeles, CA, USA) for statistical analysis.

We used structural equation modeling (Mplus 5.1), using a continuous latent SES variable indicated by the measures of annual family income and parental education and controlling for age in the analyses. For the latent SES variable, we freed the factor loading of annual family income and fixed the factor loading of the latent variable to be 1.00. Survey sampling weights, stratification, and clustering variables were applied in all model analyses. Consequently, the results are representative of the 202,539 9th and 11th grade public school children in Pennsylvania in 1999.

To determine whether the oral hygiene behaviors accounted for the SES disparity in caries prevalence and severity, the approach proposed by Baron and Kenny (23) was adopted. Specifically, we determined whether the latent SES variable was associated with caries experience at the two thresholds of disease: simple prevalence and severe caries. Next, we determined whether the latent SES variable was associated with the behavioral and preventive intervention variables. Third, we estimated the path coefficients for both the direct pathway from SES to the outcome (i.e., either simple prevalence or severe caries) and the indirect pathways through those behavior and preventive intervention variables that were associated with the latent SES variable in the second step. That is, in testing the third step of mediation, putative mediators not associated with the latent SES variable were not included in the model. Final models were then created, including only significant pathways. Based on the criteria from Fritz and MacKinnon (24) with a sample size of 530, we achieve or exceed 0.8 power when the size of the association between the latent SES variable and the outcome is large (i.e., $\tau' = 0.59$), after controlling for the mediator. This is true across all sizes of the effect of the latent SES variable on the mediator and the effect of the mediator on the outcome (i.e., α and β).

Mplus 5.1 provides multiple indices of model fit (25). The model chi square (χ^2_M) statistic tests the difference in fit between an over-identified model (hypothesized model) and a just-identified version of it; a nonsignificant χ^2 ($\alpha \geq 0.05$) indicates a good fit. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) indicate how well the model explains the data relative to a model that assumes zero population covariances among the observed variables; indices of 0.90 or higher indicate good fit. The Root Mean Square Error of Approximation (RMSEA) measures the lack of fit between the hypothesized model and the population covariance matrix. It is a 'badness-of-fit' index such that a value of zero indicates the best fit and higher values indicate worse fit; RMSEA ≤ 0.05 is considered a close fit.

Some participants were missing information about income ($n = 64$), education ($n = 11$), brushing ($n = 2$), flossing ($n = 111$), fluoridated toothpaste ($n = 36$), fluoride drops ($n = 9$), fluoridated water ($n = 170$), household size ($n = 7$), and recency of dental visits ($n = 2$). All reported analyses were conducted using expectation maximization (EM) algorithm parameter estimates to make use of partially complete data (26). This technique for handling missing data avoids sample biases that can occur when one excludes from the analyses those participants who missed one or more follow-up interviews (27). In addition, this technique provides an unbiased method for increasing inferential power when missingness is judged to be at random or completely at random as discussed by Little and Rubin (1987).

Results

See Table 1 for descriptive information about the sample. The mean age of the 9th grade students was 14.60 years (SD = 0.60); the mean age of the 11th grade students was 16.50 years (SD = 0.71); and the mean age of the sample as a whole was 15.43 years (SD = 1.15). Using the population estimate means, DMFT was significantly lower in the 9th grade students (M = 1.46, SE = 0.16) than in the 11th grade students (M = 2.12, SE = 0.18; $t(65) = -2.45$, $P < 0.02$). Income and education were associated with each other (see Table 2 for this and additional associations). The latent SES variable accounted for 46.4% of the variance in adjusted annual family income and 53.5% of the variance in maximum household education.

Table 1. Descriptive information about the sample

Variable	Percent
Ethnicity	
White	81.9
Black	14.3
Other	3.8
Simple prevalence (DMFT > 0)	49.6
Severe caries (DMFT > 3)	19.2
Annual family income[a]	
<$20 000	11.7
$20 000–$50 000	42.3
$50 001–$100 000	37.0
>$100 000	8.9
Parental education[b]	
<high school diploma	4.0
High school graduate or equivalent	30.1
Some college or technical school	21.5
College graduate	27.9
Advanced degree	16.5
Tooth brushing[c]	
<once per day	2.2
Once per day	22.7
Twice per day	55.5
>twice per day	19.6
Flossing at least once per week[d] (% yes)	65.1
Sealants (% with at least 1)	30.3
Dental utilization within the past year[e] (% yes)	86.8
Fluoridated water[f] (% yes)	39.1
Fluoridated toothpaste[g] (% yes)	98.2
Ever received fluoride drops[h] (% yes)	56.8

[a]$n = 466$; [b]$n = 519$; [c]$n = 528$; [d]$n = 419$; [e]$n = 528$; [f]$n = 360$; [g]$n = 494$; [h]$n = 512$.

In the initial models, higher SES was associated with a lower likelihood of having caries experience ($\beta = -0.30$, 95% CI = −0.57 to −0.03, $P < 0.03$; Fig. 1) and severe caries ($\beta = -0.42$, 95% CI = −0.81 to −0.04, $P < 0.03$; Fig. 2).

In the initial models, higher SES was associated with more frequent tooth brushing ($\beta = 0.26$, 95% CI = 0.14–0.38, $P < 0.0001$), greater likelihood of having dental sealants ($\beta = 0.29$, 95% CI = 0.14–0.44, $P < 0.0001$), more recent dental utilization ($\beta = 0.60$, 95% CI = 0.43 to 0.78, $P < 0.0001$) and using fluoridated toothpaste ($\beta = -0.46$, 95% CI = −0.77 to −0.14, $P < 0.005$). SES was not associated with flossing, drinking fluoridated water, or using fluoride drops.

When entered into the model predicting simple prevalence, tooth brushing, dental sealants, recency of dental utilization, and using fluoridated toothpaste did not account for the SES disparity. The final model (Table 3, Fig. 3) accounts for 12.2% of the variance in simple prevalence.

Table 2. Pearson product moment correlations among variables included the models

Measure	Income	Education	Tooth brushing	Flossing	Sealants	Recency of dental visits	Fluoridated water	Fluoride toothpaste	Fluoride drops	Simple caries prevalence	Severe caries
Age	0.01	−0.03	0.01	0.00	−0.10	−0.03	−0.03	−0.01	−0.01	0.10	0.16
Income		0.46	0.07	−0.00	0.18	0.18	0.02	−0.06	0.02	−0.19	−0.14
Education			0.14	0.00	0.17	0.24	0.07	−0.14	0.07	−0.14	−0.10
Tooth brushing				0.14	0.07	0.17	−0.02	−0.02	0.04	−0.03	−0.07
Flossing					0.01	0.13	−0.02	0.03	0.06	0.08	0.05
Sealants						0.12	0.02	−0.04	0.03	−0.04	−0.11
Recency of dental visits							−0.02	−0.05	0.09	−0.05	0.07
Fluoridated water								−0.03	−0.08	−0.01	−0.10
Fluoride toothpaste									0.04	0.06	0.02
Fluoride drops										−0.07	−0.01
Simple caries prevalence											0.50

$P < 0.05$ for correlations > 0.08. $P < 0.01$ for correlations > 0.10.

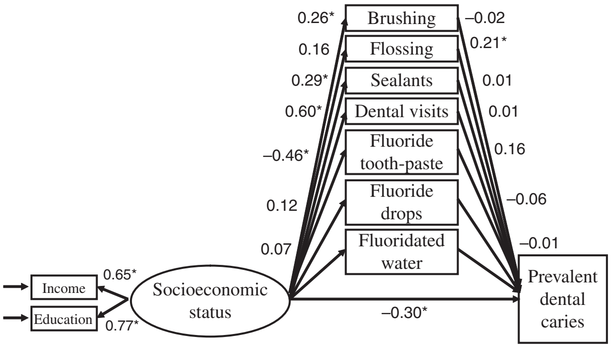

Fig. 1. Standardized path coefficients of the model for the third step in testing mediation, with simple prevalence (DMFT > 0) as the outcome. *Statistically significant path coefficient ($P < 0.05$).

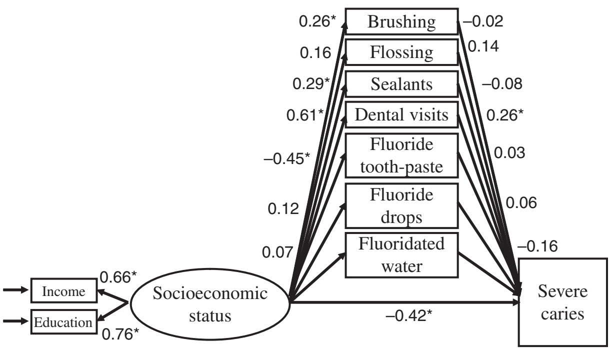

Fig. 2. Standardized path coefficients of the model for the third step in testing mediation, with severe caries (DMFT > 3) as the outcome. *Statistically significant path coefficient ($P < 0.05$).

For severe caries, the indirect path through recency of dental utilization was marginally

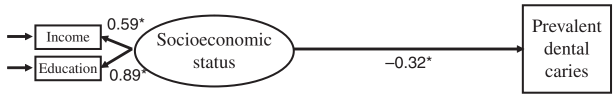

Fig. 3. Standardized path coefficients of the final model including only significant pathways, with simple prevalence (DMFT > 0) as the outcome. *Statistically significant path coefficient ($P < 0.05$).

significant ($\beta = 0.11$, 95% CI = –0.01 to 0.24, $P < 0.07$), such that higher SES was associated with more recent dental utilization, which in turn was associated with a higher likelihood of having severe caries. Thus, this path diminishes rather than accounts for the SES disparity in severe caries. In *post hoc* analyses, we examined whether severe caries mediated the association between SES and recency of dental visits. The indirect path through severe caries was marginally significant ($\beta = -0.06$, 95% CI = –0.14 to 0.01, $P < 0.08$), such that higher SES was associated with a lower likelihood of having severe caries, which in turn was associated with a higher likelihood of recent dental utilization. The final model without either path through recency of dental visits (Table 3, Fig. 4) accounts for 15.8% of the variance in severe caries.

Discussion

Consistent with studies of many other diseases and as we hypothesized, we found SES disparities in both the simple prevalence of caries experience and a measure of severe caries. We also found SES

Table 3. Fit indices and model comparisons for models of simple prevalence and severe caries

Index	Model with all behaviors and preventive strategies mediating (initial model)	Model with significant pathways mediating (final model)
Simple prevalence		
χ^2-test of model fit (df)	19.149 (13)	0.094 (1)
CFI (number of free parameters)	0.948 (41)	1.000 (11)
TLI (number of free parameters)	0.920 (41)	1.027 (11)
RMSEA	0.030	0.000
Severe Caries		
χ^2-test of model fit (df)	18.965 (13)	0.351 (2)
CFI (number of free parameters)	0.945 (41)	1.000 (15)
TLI (number of free parameters)	0.916 (41)	1.036 (15)
RMSEA	0.029	0.000

CFI: Comparative Fit Index. TLI: Tucker-Lewis Index.

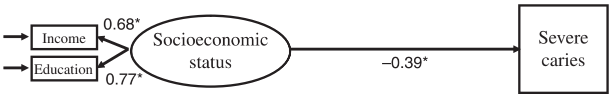

Fig. 4. Standardized path coefficients of the final model including only significant pathways, with severe caries (DMFT > 3) as the outcome. *Statistically significant path coefficient ($P < 0.05$).

disparities in tooth brushing, sealant use, and recency of dental utilization. However, contrary to hypothesis, none of these oral hygiene behaviors or preventive interventions accounted for the SES disparities in caries experience.

Although previous studies have obtained clear evidence that adolescents with lower SES and caries experience are at increased risk of having untreated decay (e.g., 7), it is less clear whether adolescents lower in SES are at increased risk of caries experience, regardless of treatment status. This distinction between untreated decay (i.e., DT) and decay regardless of treatment status (i.e., DMFT) is important, because strategies designed to reduce the disparity by removing barriers to receiving treatment may not be effective in reducing the disparity in caries experience. Although the study by Vargas et al. (7) did not find a disparity in DMFT in15–18-year old adolescents, the analysis was based on only those adolescents with at least one filled or decayed tooth. The present study, by contrast, included all adolescents, regardless of decay status. It is likely that this difference accounts for the different results across the two studies. Clearly, more large-scale studies in the United States are needed to clarify the role of SES in caries experience, so that effective policy and practice targeting caries prevention and treatment can be developed.

The SES disparity in caries experience may be partially accounted for by individual oral hygiene behaviors, such as tooth brushing and flossing, and preventive interventions, such as sealant use, fluoride exposure, and recency of dental utilization. Consistent with other studies (28), we observed SES disparities in several of these putative mediators. However, despite the SES disparities in these putative mediators, they did not account for the SES disparities in either simple prevalence or severe caries. This pattern of results is consistent with findings from children (29) and adults (30) and suggests that interventions targeting these oral hygiene behaviors and preventive interventions in adolescents will not reduce the disparity in caries experience arising from differences in SES. It remains unclear through what pathways the SES disparity in caries experience occurs. Identifying these pathways is important in creating preventive interventions. Future research should address this issue.

Although recency of dental utilization marginally mediated the relationship between SES and severe caries, the effect was to diminish rather than account for the disparity. This could occur, for example, if more regular dental visits are associated with more aggressive treatment, resulting in restorations of incipient carious lesions that would remineralize if left unrestored (31). This conceptualization, however, could not be distinguished statistically from an alternative in which severe caries mediated the relationship between SES and recency of dental utilization. Longitudinal data are required to determine the direction of the associations.

Limitations

As described above, there are limits to the conclusions that can be drawn because the study is cross-sectional and therefore cannot demonstrate causality. We believe the study has good internal validity and leave it up to the reader to decide what to conclude. An addition issue is the lack of use of radiographs, which could result in the underdiagnosis of approximal lesions. This limitation would alter the results of the present paper only if approximal lesions were associated with both SES and a mediator. To the best of our knowledge, we are unaware of such evidence.

As with any study, there is a potential for bias in the sample due to differential response. We cannot know to what extent this bias exists, however, because we have no way of knowing who did not volunteer to be in the study. Mitigating this concern are our participant recruitment procedures, in which participants were recruited in most school districts using passive, or negative, consent. Thus, we assume the bias is relatively minor. Given that the data were collected over a 2-year period, the presence of any temporal trends could confuse the data. We believe this potential problem is unlikely because there was no patterning in when schools from different income levels were assessed. Although the data were collected by five different examiner teams, they were all calibrated to an acceptable level, reducing the possibility of poor examiner reliability.

The age of the adolescents could potentially lead to several different types of bias. First, compared with the 9th grade adolescents, the 11th grade adolescents are more likely to come from families where the parents are older and therefore more likely to have a higher income. This would suggest that older adolescents would be less likely to have caries. On the other hand, older adolescents are at risk longer, which would suggest that older adolescents would be more likely to have caries. Thus, there are two opposing trends, one pushing decay rate up (older adolescents) and the other pushing the decay rate down (higher parental income). To examine these possibilities, before combining across the two ages groups, we stratified our analyses by age. We found the same pattern of results, regardless of the age of the adolescent. This suggests that the adolescent's age alone did not introduce bias into our study. To further minimize the risk of bias, we controlled for age in all our analyses.

Finally, it is possible that the caries developed earlier in childhood and not in adolescence. If this were the case, the caries would be reflecting the family's SES earlier in childhood and not the family's SES at the time of assessment. This is unlikely, however, because most adolescents in the sample with caries had received restorations. It is unlikely that some but not all caries occurring in early childhood would be restored. Cross-sectional studies such as the present one cannot entirely rule out these possibilities. Future studies employing longitudinal designs can best address these issues.

For much of the 20th Century, dental caries was studied primarily as a disease associated with risk factors such as tooth brushing frequency, flossing, sealant use, fluoride exposure, and dental care utilization. Although future studies should examine other factors known to be important predictors of dental caries such as diet and genes, different approaches may be required for the reduction or elimination of SES-based disparities in oral health. Our results suggest that SES is important in determining the caries experience of adolescents. Furthermore, we found that that this influence is not occurring through oral hygiene behaviors or preventive interventions. Given the consistent and strong role that SES effects play on so many diseases, it is surprising that so little is known about how these effects operate (32). Clearly, this is an area in need of more research if we are to be able to design successful interventions that will eliminate these SES-based health disparities.

Acknowledgements

This research was supported by a grant from the Commonwealth of Pennsylvania, Department of Health. We particularly want to acknowledge the helpful comments from the anonymous reviewers and the assistance with Mplus from Jeremy Miles.

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