A biopsychosocial model to predict caries in preschool children

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Abstract

The purpose of the study is to assess a multidisciplinary caries-prediction model. Enrolled in the study were 184 low-income children ages 3–5 years old in two Head Start programs in Connecticut. Children were examined by a dentist at baseline and at 1 year for dental caries. Each child also provided a saliva sample to obtain a measure of S. mutans. The children's caregivers completed an interview that assessed oral health behaviors, and cognitive and socioeconomic factors. The prevalence of decay (1 dmfs) increased from 40 to 58% and the number of dmfs increased significantly from 2.5 (7.1) dmfs to 4.5 (8.8) dmfs ($P < 0.001$) in 1 year. S. mutans did not change significantly. Discriminant function analysis predicting change in caries in the second year from data obtained in the first year showed that S. mutans, dmfs, and toothbrushing significantly predicted caries risk (canonical correlation = 0.5571; $\chi^2 = 51$; $df = 3$; $P < 0.001$). Children with higher dmfs, higher S. mutans, and whose parents reported more frequent brushing had more decay in the second year. None of the other behavioral, cognitive, or demographic factors was significant. The results emphasize the importance of early intervention in preventing dental caries in an underserved population. (Pediatr Dent 16:413–18, 1994)

Introduction

Biopsychosocial models of disease are being explored in a variety of health problems, ranging from lung disease to schizophrenia.[1] A biopsychosocial model of disease is highly relevant to dentistry since most oral health problems can be prevented or controlled through preventive behaviors. Recent work in caries risk assessment illustrates the potential contribution of psychosocial factors in understanding the disease process, as well as improving caries risk prediction.[2–11] Improving our prediction ability is assuming greater importance as caries prevalence declines in developed nations and relatively few people account for the majority of the caries experience.[12,13] Being able to identify more accurately those who will develop dental caries will reduce costs of preventive programs.

Studies of biological predictors of caries, such as indices of mutans streptococci (mutans), lactobacillus, and salivary fluoride levels have shown mixed results in their ability to predict caries risk. In studies of preschool children, Edelstein and Tinanoff,[14] and Thibodeau, O'Sullivan and Tinanoff[15] found that biological markers had high sensitivity but poor specificity, i.e., they are unable to distinguish those who will not develop clinical caries. Other investigators[5–8] determined that biological variables had limited ability to predict caries risk. Beck and colleagues[6] suggested that etiological models consisting solely of biological variables explained the least variation in yearly caries increment in first- and fifth-grade students. It is possible that the varying ages of the children studied, as well as varying analytical strategies, contribute to the confusion over the sensitivity and specificity of biological variables in caries risk.

Our previous cross-sectional report of 3- and 4-year-old children recruited from Head Start programs in Connecticut[16] showed that including social and psychological variables gave an improved discriminant function model of caries risk. Children with higher levels of streptococci (mutans) were more likely to be in the caries risk group. In addition, if parents believed that control of events was external to them, and reported more frequent baby bottle usage, their children were more likely to have caries than parents who had fewer external beliefs and reported less frequent baby bottle usage. Self-reported life stress and dental knowledge consistently had unexpected relationships with caries: children whose parents reported less stress and had higher knowledge scores had higher caries risk. However, the strong effects of ethnicity and socioeconomic factors still were evident, even within this relatively homogenous disadvantaged group. Children from families with lower incomes, with unemployed parents, and who were non-Caucasian were more likely to be in the caries-positive group.

The purpose of this paper is to analyze follow-up data on children still in the study 1 year later. The same multidimensional prediction model is used to explain the presence or absence of decay in the second year.

Methods and materials

The subjects of this study were 3- and 4-year-old children and their parents recruited from a population enrolled in the Head Start programs in Hartford and in New London County, Connecticut. (Head Start is a federally funded preschool program available to low-income families.) In the first year of the study 460 children were examined clinically for caries and mutans and 355 parents completed interviews providing data on social, behavioral, and cognitive characteristics of the families and children in the study. In the second year, 210 children were examined clinically and 184 parents completed an interview.

The study protocol was identical in each year of the study. Each child received a clinical dental exam and produced a saliva sample to measure mutans levels. In each year, one parent of each child completed a 15- to 20-min structured interview to obtain data on sociodemographic characteristics, locus of control, dental self-efficacy, dental knowledge, sugar intake, and perceived life stress.

Each child was examined for dental caries by two dentists trained and calibrated in clinical caries scoring. Interexaminer reliability on a separate sample of Head Start children was more than 90%. Portable dental chairs, mirrors, #23 explorers, and focusable flashlights were used but no radiographs were exposed. Caries diagnosis was based on the method of Radike,[17] and results for each child were recorded such that each tooth surface could be indicated as decayed, missing (due to caries), or filled (dmfs). All teeth missing for a reason other than caries were excluded from the analyses.

Immediately following each child's examination, a tongue blade placed on the dorsum of the child's tongue was used to obtain a sample of mutans. The sample was then impressed onto mutans-selective agar. After incubation for 72 hr, colony forming units (CFU) of mutans were counted. If the number of units exceeded 150, the child was assigned a value of 150.[15]

The questionnaire administered to the caretaker tried to determine histories regarding the child's antibiotic use, sugar intake, baby bottle use, and toothbrushing behaviors. Antibiotic use in the first year was measured by asking respondents how often their child had received a prescription for an antibiotic from a physician since birth.

For diet, respondents were asked a series of questions about how often their child had eaten five foods high in sugar content during the last week. Responses scored on a scale from not at all (1) to once or more a day (5) and were summed to obtain a total score that could range from 5 to 25.

Two sets of questions were used to tap important oral health behaviors. Parents were asked whether their children ever took a bottle with milk or juice to bed at night and, if so how frequently: a couple of times, sometimes, pretty often, very often, or every night. Toothbrushing habits were examined by asking the caregiver how frequently brushing was done: never, less than once a day, once a day, twice a day, more than twice a day.

Table 1. Clinical oral health status, Year 1 (N = 460)

Mean (SD) number decayed surfaces	1.8 (3.7)
% with active carious lesions	41%
Mean number dmfs	2.8 (6.9)
% 1 dmfs	44%
Mean (SD) CFUs	48.9 (63)
% Mutans group	
0	18
1–50	47
> 50	39

Cognitive measures on dental knowledge, Dental Health Locus of Control, and Dental Self-Efficacy were developed specifically for this study. Dental knowledge was assessed by means of a 10-item true/false questionnaire. Questions pertained to causes of caries, dental treatment, baby bottle usage and toothbrushing. Dental Health Locus of Control included five statements about how much control over dentist's behavior, information, and dental treatment the parent desired. Respondents stated whether the statement was true or not true for them. The scale ranged from 0 to 5, with a higher score indicating higher externality or greater preference for others to have control. A Chronbach's alpha of 0.57 indicated that the scale has marginally acceptable internal reliability.

The Dental Self-Efficacy Scale was an eight-item questionnaire that assessed the respondents' confidence in their ability to perform specific preventive dental and treatment behaviors despite any other obstacles. Respondents were asked to rate their confidence in their ability to do each behavior on a four-point scale, ranging from being extremely sure (4) to not sure at all (1). Summed responses ranged from 8 to 32. Chronbach's alpha is 0.70, indicating acceptable internal reliability.

In addition, a revised version of the Holmes and Rahe Life Events Questionnaire[18] was used. Caregivers were asked to indicate whether each of 41 events listed in the questionnaire occurred to them and then, based on the work of Lazarus and Folkman,[19] to rate how stressful they thought the event was on a six-point scale from no stress at all (0) to extremely stressful (5). Scores ranged from 0 to 205.

Along with psychosocial questions, information obtained on family characteristics included: race, age of the child and parent, family size, education of the parent, and family income.

Results

Tables 1 and 2 present a summary of the clinical and social characteristics of the children generated from the parent questionnaire.

Caries distribution in this sample was negatively skewed, with most children having few active or treated carious lesions. Forty-one percent had active carious

Table 2. Demographic, behavioral, and attitudinal characteristics of the sample, Year 1 (N = 355)*

Demographic	
Age of child (mean months/SD)	46.3 (5.7)
Family size (mean/SD)†	4.2 (1.5)
Education (mean years/SD)	11.7 (2.3)
Parent age (mean years/SD)	28.5 (7.2)
Income	
< $10,000	53%
$10,000–15,000	29%
> $15,000	18%
Race/ethnicity	
Caucasian	20%
African-American	50%
Hispanic	30%
Behavioral	
Antibiotics (no. since birth)(mean/SD)	3.3 (2.7)
% Night-time baby bottle use (ever)	
Never	28%
Couple/sometimes	25%
Pretty/very often	15%
Every night	32%
% Brushing frequency	
Once a day	24%
Twice a day	50%
> Twice a day	27%
Sugar intake scale (mean/SD; range = 7–35)	14.3 (3.8)
Cognitive	
Dental health locus of control (0–5)	2.8 (1.5)
Perceived stress (mean/SD; range = 5–205)	17.2 (15)
Self efficacy (8–32)	21.5 (4.7)
Dental knowledge (0–10)	7.8 (1.4)

* Number of children for whom both clinical exams and questionnaire data were obtained.

† Total number of persons living in the household.

lesions and 44% had one or more dmfs at study entry, with a mean number of decayed surfaces of 1.8 (SD = 3.7) and a mean dmfs of 2.8 (6.9). As in other studies,[6,7,13] most of the decay was experienced by a minority of the children.

Mutans distribution also was negatively skewed, with most children having either no discernible CFUs (18%) or fewer than 51 (61%). The mean number of CFUs was 48.9 (SD = 63). Thirty-nine percent (39%) of the children had moderate to high levels of mutans with 51 to 150 colonies.

Table 2 shows that most children were about 4 years of age and in families of about four people. Most parents were in their mid- to late-20s and most had a high school education. Most of the families had incomes less than $15,000 and more than half had incomes less than $10,000. The sample consisted predominantly of African-Americans (50%) and Hispanics (29%); 20% were Caucasian.

Table 3. Year 1 and Year 2 clinical oral health status of children remaining in the sample (N = 210)

	Year 1	*Year 2*
Mean (SD) number decayed surfaces*	1.5 (3.5)	2.4 (3.7)
% with active carious lesions	37%	55%
Mean number dmfs	2.5 (7.1)	4.5 (8.8)
% 1 dmfs	40%	58%
Mean (SD) CFUs	49.2 (62)	44.5 (59)
% Mutans group		
0	22%	23%
1–50	45%	49%
> 50	33%	28%

* Paired *t*-test shows significant increase in decayed surfaces and dmfs from Year 1 to Year 2 ($P < 0.001$) for those remaining in the study.

Parents reported fairly frequent use of antibiotics to treat infections since birth. Baby bottle usage at bedtime also was a common practice, with 32% reporting that they put the child to bed with a bottle every night and only 28% saying that their children never used a baby bottle at night. Parents reported that children brush their teeth at least once a day and most reported twice a day. Moderate levels of sugar intake also were found.

Parents appeared to be external in their beliefs about locus of control, preferring dentists or other professionals to manage their dental care. Parents were quite knowledgeable about factors that influence dental caries, reported moderate levels of perceived stress, and were confident of their ability to care for their own oral health needs and those of their children.

Table 3 presents data on the clinical status of children who remained in the study in the second year for both first- and second-year variables. Thus, comparisons can be made among those who were in the study in the first year and those who remained in the study in the second year. The first column presents the clinical oral health status in Year 1 for children who remained in the study, and the second column shows values on the same variables in Year 2. A comparison of decayed surfaces and dmfs in Tables 1 and 3 indicates that the children who remained in the study in Year 2 did not have significantly less decay than the children in Year 1.

Table 3 also shows that the number of decayed surfaces increased significantly from 1.5 (SD = 3.5) in the first year to 2.4 (SD = 3.7) ($t = 4.00$; df = 207; $P < 0.001$) in the second year. The total number of dmfs increased

Table 4. **Year 1 and Year 2 demographic*, behavioral, and attitudinal characteristics of children remaining in the sample (N = 184)**

Demographic	*Year 1*	*Year 2*
Age of child (mean months/SD)		46.1 (5.2)
Family size (mean/SD)	4.1 (1.4)	4.3 (1.6)
Education (mean years/SD)†		12.1 (1.9)
Parent age (mean years/SD)		28.2 (5.9)
Income		
< $10,000	53%	46%
$10,000–15,000	30%	38%
> $15,000	17%	16%
Race/ethnicity		
Caucasian		24%
African-American		50%
Hispanic		25%
Behavioral		
Antibiotics (no. since birth)(mean/SD)	3.1 (2.7)	1.1 (1.8)
% Night-time baby bottle use (ever)		
Never	29%	
Couple/sometimes	21%	
Pretty/very often	16%	
Every night	34%	
% Brushing frequency		
Once a day	14%	
Twice a day	55%	
> Twice a day	30%	
Sugar intake scale (mean/SD; range = 7–35)	14.3 (4)	14.1 (4)
Cognitive		
Dental health locus of control‡	2.9 (1.5)	3.1 (1.5)
Perceived stress (mean/SD; range = 5–205)	16.8 (15)	13.8 (15)
Self efficacy (8–32)	21.6 (4.5)	21.4 (4.6)
Dental knowledge (0–10)		7.9 (1.4)

* Year 1 and Year 2 values are equivalent for the demographic variables because the data were collected only in Year 1 and would not change. The exceptions are family size and income, which were measured in both years.

† Those who remained in the sample Year 2 had significantly more education than those in Year 1 ($P < 0.01$) using one-way analysis of variance.

‡ Paired *t*-test showed a significant increase in the dental health locus of control scale ($t = 2.6$; $P < 0.01$), although this is not a large change and may not be clinically significant.

significantly from 2.5 dmfs (SD = 7.1) in Year 1 to 4.5 dmfs in Year 2 ($t = 7.5$; df = 207; $P < 0.001$). The prevalence of decay increased from 41% of the sample in Year 1 to 55% of the sample in Year 2. The prevalence of mutans did not change significantly.

A comparison of Tables 2 and 4 indicates that the subset of parents who remained in the study in Year 2 were significantly more educated than those who participated in Year 1. Caucasians also constituted a higher proportion of the sample in Year 2, and Hispanics comprised less of the sample, although these differences were not significant.

Few differences were found in behaviors or beliefs and attitudes from Year 1 to Year 2, except that parents state that children were brushing their teeth more frequently in the second year and caregivers' scores on DLOC increased slightly.

Because of the skewed distribution of the number of decayed surfaces, the dependent measure was dichotomized as the presence or absence of decayed surfaces in the second year. Discriminant function analysis was used to predict group membership in either the group having decay or not having decay in the second year. Hierarchical discriminant analysis assessed the contribution of biological, behavioral, attitudinal, and demographic factors to the prediction model. The biological variables, entered first, were Year 2 mutans and Year 1 dmfs. The behavioral variables, entered next, were antibiotic use, sugar intake, brushing frequency, antibiotic use, and night-time baby bottle use in Year 1. Cognitive variables, added third, included perceived stress, self-efficacy, DLOC, and dental knowledge in Year 1. Demographic factors were included in the function last; these were child's age, family size, education, and age of the parent, family income, and race.

Table 5 presents the results of the discriminant analyses. Mutans and dmfs in Year 1 are the best caries predictors in Year 2 and by themselves these variables explain 25% of the variation in decay in Year 2 (canonical correlation = 0.50; $\chi^2 = 57.7$; df = 2; $P < 0.001$). Adding the behavioral variables to the function increases the variation explained to 28% (canonical correlation = 0.53; $\chi^2 = 56$; df = 3; $P < 0.001$). Brushing frequency was the only significant behavioral predictor of caries change. However, the direction of the relationship indicates that more frequent brushing was associated with *more* decay.

Adding cognitive variables to the equation detracts from the predictive ability of this model, as the variation explained declines to 27% (canonical correlation = 0.52) $\chi^2 = 52$; df = 3; $P < 0.001$). Finally, when the demographic characteristics are included in the function, the variation explained increased to 32% (canonical correlation = 0.5571; $\chi^2 = 51$; df = 3; $P < 0.001$). None of the individual variables was significant, but as a block, the demographic variables improve the ability of the discriminant function to predict caries.

Discussion

The high attrition rate in the sample (> 50%) is cause for concern in interpreting the results and

Table 5. Results of the discriminate analysis predicting decay in Year 2

Step	Group Variable	Individual Variables	Canonical R^2	Chi-Square (df)	F
1	Biological		0.25	58 (2)*	
		Mutans levels			53*
		dmfs			33*
2	Behavioral		0.28	56 (3)*	
		Brushing frequency			22†
		Sugar intake			NS
		Antibiotic use			NS
		Baby bottle use			NS
3	Cognitive		0.27	52 (3)*	
		Dental locus of control			NS
		Dental self-efficacy			NS
		Dental knowledge			NS
		Stress			NS
4	Demographic		0.32	51 (3)*	
		Education			NS
		Income			NS
		Family size			NS
		Parent age			NS
		Race/ethnicity			NS

* $P < 0.001$.
† $P < 0.01$.

applying them to other populations. Those who dropped out of the sample seem to have more caries (although differences are not significant) and have caregivers with relatively lower education levels. By losing the highest-risk children, the explanatory variables may be less effective in predicting caries in this group. Although our ability to generalize from the results may be limited, the data are useful in characterizing change in caries status over time and in fitting a prediction model that includes behavioral, cognitive, and demographic, as well as biological factors.

As would be expected in preschool children, few children were caries positive in the first year of the study. A relatively small number of the children account for most of the decay in this group. Only 9% of the sample in the first year and 15% in the second year have five or more decayed surfaces, which is consistent with other studies of school-aged children. However, it is distressing that the prevalence of decay (1 dmfs) increases from 40% in Year 1 to 58% of the sample in Year 2. The number of dmfs increases significantly as well, from 2.5 (7.1) to 4.5 (9) dmfs in 1 year. The percentage of unmet need, measured by percent of decayed teeth divided by total dmfs, declines slightly from 60 to 53%, but still represents a substantial need for treatment in this economically disadvantaged group.

The 1986–87 NIDR[13] study conducted in of US children found that 50% of children were caries free at age 5. The mean dfs was 3.9 and the percent of decayed teeth divided by total dfs was 28%. By any measure, the children in this sample have substantially worse dental health than a national sample of American children. The decay rate in this sample is more similar to that of Aiken, South Carolina, where 57% of the first graders were caries positive compared with Portland, Maine, where only 31% of the first graders were caries positive.[6] Although the Head Start program requires dental screenings and treatment of the most severe caries, the results strongly suggest that these children and their families have serious barriers to dental care.

Consistent with other studies of caries risk in children, our study found mutans levels and previous dmfs to be important predictors of caries.[4–13] More mutans and higher dmfs are predictive of future caries incidence. While mutans levels probably fluctuate somewhat in individual children, the mutans scores do not appear to change significantly from year to year in this sample. The findings suggest that factors contributing to higher mutans scores and to dmfs in Year 1 contribute to establishing an environment of developing more and new caries in subsequent years. The implication is that once a caries pattern is established, it will be difficult to reverse. This finding is worrisome because of the young age of the children studied. The results strongly support an argument for the earliest possible intervention to prevent decay — before it develops and establishes a childhood pattern of disease.

One behavioral variable added significantly to the prediction model. Surprisingly, children whose parents reported more frequent brushing have higher risk of decay. These results are difficult to explain and suggest that more in-depth questioning about oral hygiene behaviors are needed to evaluate the effects of oral hygiene on caries risk in this sample. It is possible that parents overestimate brushing frequency or that children who have more decay have been advised to brush more frequently by their dentists.

In these analyses, none of the cognitive variables had a significant effect on the risk of having decay in the second year. This could be because their effects on caries risk are indirect through the effects of behaviors. Tedesco et al.[2] in studying cognitive factors in predicting compliance and clinical outcomes in periodontal disease found that self-efficacy predicted behaviors but not clinical indices. Because of the distributional properties of the dependent variable, path modeling to assess these inter-relationships was not possible.[20] Future work should address the potential of structural modeling to analyze the direct and indirect effects of cognitive factors on caries risk.

Previous results on the cross-sectional relationships among biological, cognitive, and behavioral variables in this sample of preschoolers[16] demonstrated a significant effect for all three elements of the model. The follow-up data suggest that caries risk may be influenced by cognitive and behavioral variables while children are still toddlers, but that once caries patterns are established they progress through the preschool years.

Conclusions

1. The prevalence of decay (1 dmfs) increases from 40% in Year 1 to 58% of the sample in Year 2. The number of dmfs increases significantly as well, from 2.5 (7.1) to 4.5 (9) dmfs in 1 year ($P < 0.001$). The prevalence of decay is much higher than expected compared with other studies of school-aged children.
2. The most important predictors of future decay are dmfs in the previous year and *S. mutans* levels. These two variables explain 25% of the variation in decay in Year 2.
3. Although the results on the effects of toothbrushing on decay are not in the predicted direction, it may be that those who already have decay may be brushing more frequently to prevent future decay.
4. Because of the distributional properties of the dependent variable, path modeling could not be used to assess these inter-relationships among cognitive, behavioral, and biological variables. Future work should address the potential of structural modeling to analyze the direct and indirect effects of cognitive factors on caries risk.
5. The results support the argument for the earliest possible intervention to prevent caries, because it appears that once caries patterns are established in economically disadvantaged and minority children, they progress through the preschool years.

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