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Assessment of the Relationship between Neighborhood Characteristics and Dental Caries Severity among Low-Income African-Americans: A Multilevel Approach

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Abstract

Objectives—To assess the relationship between neighborhood effects and the severity of dental caries among low-income African-Americans.

Methods—A multistage probability sample of African-American families living in the poorest 39 census tracts in Detroit was drawn. During 2002–03, cross-sectional data of a cohort that includes 1021 caregivers were collected in the first of three waves of interviews and examinations. Multilevel analyses focused on 27 neighborhood clusters and involved a combination of individual (Level-1) and neighborhood (Level-2) data including census and geocoded (address matching to census geographic areas) information.

Results—There is significant variation in the severity of caries between low-income neighborhood clusters. Caries severity decreases with a higher number of churches, while it increases with a higher number of grocery stores in the clusters after accounting for individual characteristics. Only 14% of the inter-individual variability in caries was explained by classical individual risk factors for this condition.

Conclusion—Neighborhoods contribute something unique to caregivers' oral health, beyond socioeconomic position and individual risk factors. Multilevel interventions are necessary to reduce disparities among African-Americans and churches may offer a promising venue from which to conduct them.

Keywords

African-American; dental caries; multilevel analysis; neighborhood effects

Introduction

The growing importance of chronic diseases in the industrialized countries has been accompanied by a shift in risk factor research from environmental to individual–level factors (1). But to date, individual–level factors have not fully explained the prevalence of an array of diseases of importance to public health, so interest is reawakening in the role of neighborhood

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characteristics in shaping individually based risk factors and behaviors (2). With respect to oral health, intra-group disparities among poor African-Americans may be related to specific features of their area of residence and the interaction between these features and individual risk factors. This may require the development of new ways to redirect interventions from the individual to the community level (3–10).

Current etiologic models of dental caries are predominantly based on dynamic processes taking place only within the individual oral cavity. This may partly explain the caries etiology, but it has been argued that biological causation alone is insufficient to explain the variations in caries experience among populations (11). Determinants of individual health are not always the determinants of population health (12), and dental researchers have not yet linked macro social forces, such as neighborhood characteristics, with patterns of oral health status and disease in populations.

There are several reasons why neighborhood environments may affect dental caries in negative or positive ways. Availability of, and access to, healthy foods may differ across areas (1,12), as may availability and access to dental care. Neighborhoods with high crime levels, poor lighting, and bad transportation systems may limit the mobility of the residents (12,14), affecting not only motivation to seek dental care but also such things as residents' food shopping patterns. Difficult day-to-day living conditions can also lead to psychological stress and even clinical depression (13), though the extent to which dental caries is so affected has not yet been well-explored.

Neighborhood environments may also present positive opportunities to enhance social support networks, act as stress buffers, and promote healthier standards (14). For example, there is evidence to show that membership in social institutions, such as religious organizations, is positively correlated with better health outcomes (15–17). This association may be mediated by social support processes including enhanced individual self-esteem and an increased sense of positivism (15). However, it is not clear what potential factors may mediate the relationship between the place of residence and the likelihood of having poorer oral health. As a consequence, research in oral health disparities has yet to reach its goal of understanding the effects of area characteristics, and how targeting these effects may promote fresh approaches to oral health promotion.

This study is a multilevel analysis to assess the association between neighborhood characteristics and dental caries. Three different issues are explored: a) variation in caries severity between and within neighborhood clusters; b) neighborhood and individual level predictors' influence on the explanation of caries variation between and within clusters; and c) direct effects of neighborhood predictors on caries severity.

Methods

Study sample

The target population of this study is low-income African-American children under age six and their main caregivers who resided in Detroit, Michigan. The main caregiver was defined as the individual who is responsible for feeding, bathing, and nurturing a child emotionally, mentally, and physically at the primary home of residence. The current analyses focused only on caregivers.

Sampling method

This analysis uses data from the first wave of investigation of determinants of oral health disparities that is conducted by the Detroit Center for Research on Oral Health Disparities. The selection of participants was based on a stratified two-stage area probability sample of

households in 39 selected low-income census tracts in Detroit. In the first stage, 1,526 census blocks were the primary sampling units. A total of 118 segments (groups of blocks) were created so that each segment contained at least 100 households. In the second stage, trained study staff went to each of the 118 segments to list all housing units on listing forms. Approximately 14,000 housing units were listed and a total of 12,655 housing units were selected. Trained interview staff visited each sample housing unit to screen for eligibility. This yielded a sample of 1,021 pairs of children and their main caregivers for analysis. Institutional Review Board clearance was obtained prior to the initiation of the data collection process. The response rate was 60.6% and takes into account the contact rate for non-contacted and non-occupied households. Clusters where participants did not respond were not included in the analysis. The second wave of data collection and an educational intervention are in progress (2003–2005). (A more detailed description of the sampling procedure is available from the authors upon request).

Definition of neighborhood

Census tracts are administrative boundaries and do not necessarily represent objectively similar communities or neighborhood characteristics. Therefore, the 39 tracts were clustered into 27 neighborhood clusters based on three factors: a) proximity of tracts; b) transportation/street boundaries; and c) location of neighborhood frames of reference such as neighborhood associations. The 27 neighborhood clusters represent a range of one to three tracts per group, with an average population of 2,776. Further analyses were based on these 27 clusters and not the original 39 census tracts.

Outcome measure

Dental caries was measured by the criteria developed by the International Caries Detection and Assessment System (ICDAS) (18). Caries diagnostic codes were recorded on a scale from zero (sound) to six (distinct cavitation with visible dentin). The number of untreated decayed tooth surfaces per adult was used to determine the severity of caries.

Individual characteristics (Level – 1)

The interviews of the participants yielded demographic data (e.g., age, income, education, and employment status), social determinants of oral health behaviors, and practices including social support, religiosity, and self-perception of oral health. A food frequency questionnaire (Block Dietary Systems, Berkeley®, CA) was administered to caregivers to assess their dietary practices, and oral hygiene status was measured by the Patient Hygiene Performance Index (19). Table 1 lists the individual characteristics used in the study.

Neighborhood characteristics (Level-2)

Data about neighborhoods were obtained from two different sources. First, the online national yellow pages directory was used to obtain a list of addresses of dentists, grocery stores, and churches in each of the 27 neighborhood clusters. The list of addresses came from a search using the 21 zip code areas that covered the census tracts selected. Using a geocoding tool (20), 117 addresses of dentists, 478 addresses of churches, and 264 addresses of grocery stores were located in the 27 neighborhood clusters of interest.

The second source of data was the 2000 Census Summary Files 1 and 3 (SF1-SF3) (20). The selection of Level-2 characteristics was guided by neighborhood-based research and theory (4,9,21), and reflects three main neighborhood dimensions: wealth, social disadvantage and housing infrastructure (Table 2).

Preparation of neighborhood data

Factor analysis was conducted to control multicollinearity problems that would arise if all individual census data variables were analyzed simultaneously in a linear model (9). The analysis revealed that the 10 census tract measures were reduced into three empirical factors (explained variance = 46%, 29%, 21% respectively). The first factor contained high loadings on the percent of families that are female headed (0.89), percent of households with public assistance income (0.76), the adult unemployment rate (0.75), and the percent of people that use public transportation (0.75). The label *Social Disadvantage* is used to describe this factor. The second factor contained high loadings on the percent of households with no kitchen (0.67), plumbing (0.80) and telephone (0.70). The label *Housing Infrastructure Deficiency* is used to describe this factor. The third factor contained high loadings on the median household income variable (0.69) and the percent of individuals over 16 years old receiving income regularly (0.88). This last factor was labeled as *Wealth*.

The loadings for each factor were used to compute a social disadvantage score, housing infrastructure deficiency score, and a wealth factor score for each cluster (9), using PROC SCORE in SAS (22). The three factor scores were added to create a neighborhood socioeconomic disadvantage score (4,7,21,23) (range from −3.44 to 2.76 SD). Standardized scores represent the deviation of the value from the mean. The higher the SES disadvantage score, the greater the degree of privilege in the neighborhood cluster, and the lower the score the more disadvantage. All other neighborhood characteristics (dentists, grocery stores, churches, residential mobility and vacant housing) were standardized (using the mean and standard deviation of each specific variable) with the purpose of having all the variables in a common metric, and decreasing the difficulty when interpreting the multilevel regression coefficients.

Analytic approach

The statistical program SUDAAN (24) was used to obtain estimates of the distribution of each individual level predictor and the bivariate association estimate with the main outcome of interest through analysis of variance. All analyses were based on fully imputed data (Item missing values were replaced with a regression imputation value following a procedure developed by Raghunathan *et al.* (25), and used sampling weights to compensate for unequal probabilities of selection and non-response among households.

A sequence of three hierarchical linear models was explored using PROC MIXED in SAS. First, a fully unconditional model was used to explain if there was significant variation in the caries severity measure between the 27 neighborhood clusters. This model allowed partitioning the total variance of the outcome into within-group variance (individual level) and between-group variance (neighborhood level) (26). Second, individual-level predictors were included to model the outcome in a variance component model (26,27). This model helped explain the proportion of caries variance within the neighborhood clusters that was accounted for once the individual predictors were examined. Finally, neighborhood-level predictors were included to assess whether they had any influence in explaining the variability of caries among the neighborhood clusters in an intercept-as-outcome model (26,27). For the model building process, all Level-1 predictors were dichotomized and the continuous Level-2 predictors were grand mean centered, as specified previously. The variance-inflating factor estimates and the correlation matrix did not reveal collinearity problems. Additional adjustment for the neighborhood cluster total population did not affect substantially the estimates described below.

Results

The total sample size was 1,021 caregivers. There were 16 edentulous caregivers excluded, so 1,005 caregivers are included in the following analyses. Dental examinations showed strong inter and intra examiner reliability as demonstrated by the kappa coefficients (Inter: 0.83 (95% C.I = 0.81, 0.85), Intra: 0.74, (95% C.I= 0.71, 0.77)). Caregivers ranged in age from 14 to 70 years with an average of 29 years. The majority of the caregivers were female (95.5%) and were not employed at the time of the survey (63%). Almost 46% of caregivers had some high school education but no degree, 32.2 % held a high school diploma, 19.3% had some college but no degree, and only 2.9% had a college or professional degree.

Results from the bivariate analysis (Table 3) showed a higher number of untreated decayed surfaces among caregivers who were unemployed at the time of the survey. The association between perceived oral health and untreated dental caries showed a very consistent gradient; the poorer the perception that caregivers had about their oral health, the higher the mean untreated decayed surfaces. Caregivers who seemed to have more religious involvement and reported having instrumental and emotional social support had fewer untreated decayed surfaces. As for the behavioral predictors, it can be concluded that those caregivers with poor oral hygiene had a significantly higher number of decayed surfaces. Likewise, those caregivers who had above-median total sugar intake had a significantly higher mean of untreated decayed surfaces.

Table 4 shows the results from the different multilevel models. Model 1 (Fully Unconditional Model)) showed that the average neighborhood cluster caries level in this sample of tracts was 29.9 untreated decayed surfaces. Regarding the random effects, the estimated value of the between-neighborhoods variance was statistically significant ($p= 0.05$). This finding suggested that these neighborhood clusters differed in their average caries level. There was even more variation among caregivers within-neighborhood clusters.

When individual-level characteristics were added (Model 2- Variance Component Model), it was observed that that caregivers older than 25 had 2.2 more untreated decayed surfaces than their younger counterparts. On average, those caregivers who were unemployed had untreated decayed surface values 2.5 times higher than the employed, and those with poor self-perception of their oral health had a untreated decayed surfaces score that is 6.2 higher than those with good to excellent self-perception. Caregivers with poor oral hygiene scored 6.8 untreated decayed surfaces more than those with good oral hygiene. Finally, an increase of 2.5 untreated decayed surfaces was observed for those caregivers whose total sugar consumption was above the median (227gr/day). All these findings were true when controlling for the other predictors in the model. The predictors mentioned above were all statistically significant ($p < 0.05$). The final between-neighborhoods variance indicated there was still some caries variation in the neighborhood clusters remaining to be explained ($p = 0.03$). Within the neighborhood clusters, the selected individual fixed predictors explained 14% of the inter-individual variance in caries. Model 2 demonstrated that the between-neighborhoods caries variance was still significant after accounting for individual-level predictors.

In Model 3, the Intercept-as-Outcome Model, neighborhood predictors were included to assess if they had any influence in explaining the variability of untreated decayed surfaces *among* the neighborhood clusters. It was observed that the characteristics of the neighborhoods affected the severity of dental caries, even when individual characteristics were accounted for. Specifically, for every one standard deviation (SD) unit increase in the number of neighborhood cluster's churches, the average number of untreated decayed surfaces significantly decreased by 2.7, holding all else constant. This finding remained significant even after statistical adjustment for individual social support as shown in Model 4, which suggested that the effect

of churches on caries was not confounded by this specific characteristic, as churches may act as a distal indicator of unmeasured individual social support. Individual social support (emotional support) may be conceptualized as a mediating factor in the association between churches and dental caries, which supports the growing evidence of the relationship between social institutions such as religious organizations and better general health (16,17,28). On the other hand, the average untreated decayed surfaces score significantly increased by 2.1 for every SD unit increase in the number of grocery stores. These findings were statistically significant (p=0.05) even after adjusting for the total population of the neighborhood clusters. Moreover, there was a untreated decayed surfaces decrease of 0.6 units for every one standard deviation unit increase in the composite score of neighborhoods' SES disadvantage (i.e., less disadvantage), as well as for every SD increase in the number of dentists (untreated decayed surfaces decreased by 0.7 units). Models 3 and 4 showed an increase in untreated dental caries for every one SD unit increase in the percent of vacant housing, but this relation did not reach statistical significance. None of the interactions explored between second level predictors reached statistical significance. Consequently, they were not included in the final models. The final variance estimate between neighborhoods indicated there was no more variation in the untreated decayed surfaces measure between the clusters remaining to be explained (p= 0.09) after accounting for these neighborhood characteristics. In general, the selected neighborhood predictors explained 48% of the variance in untreated decayed surfaces between the neighborhood clusters.

Discussion

This research took advantage of multilevel techniques, which provide an efficient way to link the conventionally distinct ecological and individual-level studies. Second, the problem of neighborhood definition was directly approached by developing a clustering process based on proximity of tracts, street boundaries, and local neighborhoods' frame of reference to reflect neighborhood limits more objectively, not relying exclusively on census fixed boundaries. Also, the use of a probability sample and sampling weights allowed the results to be generalized to the greater low income African-American care-givers of Detroit.

Multilevel models allow investigation of several interrelated research questions. The initial research question that arises in this analysis is that of how much neighborhoods vary on the health outcome measure. The average variation in the severity measure of dental caries at the neighborhood cluster level was relatively small (Intraclass Correlation Coefficient = 2.4%). It has been reported (29) that when neighborhood sizes are large (e.g., clusters of tracts), variation within neighborhoods may be high; consequently, variation between neighborhoods may be limited and it may be more difficult to detect neighborhood effects (29).

As seen with Model 1, the Fully Unconditional Model, the within-neighborhoods variation in dental caries was significantly much larger than the variation found between the neighborhood clusters. A natural follow-up to the unconditional partitioning of variation, described previously, is to assess the extent to which observed variations within neighborhood clusters are due to characteristics of the individuals residing in them. Once major risk factors for dental caries were accounted for, on average only 14% of the variance in caries within the neighborhood clusters was explained by individual level factors. This finding suggests that there are factors other than the classical parameters (e.g., access to care, oral hygiene, sugar intake, self-perception of oral health, and individual socioeconomic status) to which adequate attention has not been paid. Recognition of this may broaden understanding of the causes of intra-group oral health disparities. For example, the authors of this study had no information on the caregivers' bacterial and salivary factors, which might have helped to better explain the great variability within these clusters.

Two particular neighborhood characteristics were found to have consistent effects on caries severity. These were a) the number of churches in the clusters, associated with lower caries levels; and b) the number of grocery stores in the clusters, associated with higher caries levels.

The presence of churches may be a proxy for the degree of social support within the neighborhood clusters, and this type of support is theoretically related to the constructs of social capital (12) and social cohesion (9). These constructs refer to processes that may exert a positive influence within a collective environment to the benefit of residents. Another theoretical explanation for the observed association between presence of churches and dental caries may be that these social institutions reflect unmeasured effects of social support at the individual level. The magnitude of the decrease in dental caries attributed to a higher number of churches remained virtually the same after statistical adjustment for the covariate representing emotional support, thus reducing the possibility of residual confounding affecting this finding.

With increasing health disparities in morbidity and mortality between African-Americans and other racial groups, and within the African-American population, researchers have begun to explore alternative strategies for providing health interventions to African-American communities. The church has historically been a focal point of the spiritual, social and political life of African-Americans, and it is a strategic venue in which social factors associated with health behaviors can be addressed (12,30). Hence, health interventions such as oral health promotion programs are likely to fit well within the church's priorities.

With respect to grocery stores, there is a higher risk of having dental caries with an increasing number of grocery stores in the neighborhood clusters. The population density per food market is much greater in poor neighborhoods, while the quality of food available is poorer (31). As a result, the barriers to making healthier food choices in low-income communities may be overwhelming, and may therefore contribute to higher rates of dental caries since the link with poor nutrition and sugar intake has been documented (32). There is a need to study in detail the type of foods and snacks available in grocery stores in low-income neighborhoods in Detroit as compared with middle and high-income neighborhoods.

There were some limitations in this study. First, the online yellow pages directory used to obtain the number of dentists, grocery stores and churches may be incomplete, and therefore some underestimation in these exposures is possible. These errors may bias the point estimates of effect towards the null value, underestimating the true exposure-disease relationship (33). Second, the cross-sectional nature of the data used in this analysis did not allow the investigation of the directionality of the associations or the opportunity to clarify the time frame of the exposures. Risk factors for dental caries are cumulative and may have occurred when people lived elsewhere. Finally, most multilevel studies of neighborhood effects are very concerned about confounding by individual socioeconomic status. That possibility is diminished by the fact that the sampling method from which this population was drawn considered only census tracts where there was the highest proportion of households with incomes below the 200th percentile of the federal poverty level. Still, there is always a possibility of some residual confounding by other behavioral and psychological characteristics in studies of this type. Future research on contextual effects on dental caries should try to do direct quantification of neighborhood characteristics that could be used as one way to reduce misclassification error in exposure data. Moreover, studies might look at other Level-2 contexts (e.g. family, worksite) to capture other processes involved in caregivers' knowledge, attitudes and behaviors related to caries.

There are features of the neighborhood environments that influence the oral health of those individuals exposed to them either in addition or in interaction with individual characteristics

and should be carefully considered when implementing dental caries prevention programs among income African-Americans.

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TABLE 1

Distribution of Level-1 predictors (individual characteristics)

Predictor	Frequency	Weighted %
Age		
14–24 years	342	33.6
25–35 years	486	49.6
36–46 years	144	12.8
>=47 years	49	4.1
Employment Status		
Yes	390	37.1
No	627	63.0
Family's income in last 12 months		
< $10,000	448	44.5
$10,000–$19,999	282	27.1
$20,000–$29,999	166	15.9
>= $30,000	125	12.4
Rate the availability of dental services to you and your family		
Excellent	163	16.6
Very Good	200	20.8
Good	291	28.6
Fair	255	24.4
Bad-Very Bad	102	9.6
Perception of mouth and teeth		
Excellent-Very Good	85	9.2
Good	219	20.9
Fair	434	41.3
Poor	283	28.6
Social support		
Count on someone to give you reassurance		
Yes	910	91.5
No	86	8.5
Oral hygiene status (PHP Index)		
Good	556	54.5
Poor	465	45.5
Total sugar intake		
<227 gr/day i	626	61.3
>228 gr/day	395	38.7

TABLE 2

Descriptive characteristics of neighborhood predictors among the 27 neighborhood clusters

Census Data		
Median household income (US$)	22,390	4,776
Characteristics	Mean	SD
Percent female householder	43	6.5
Percent vacant housing units	13.2	4.8
Percent high school graduate or higher	33.1	4.4
Percent unemployed	10.8	4.5
Percent using public transportation	14	5.4
Percent lacking plumbing facilities	1.5	1.4
Percent lacking kitchen facilities	1.3	1.1
Percent with no telephone service	10	3.5
Percent with public assistance income	17.2	6.3
Percent living in the same address since 1995	59.3	11.3
Percent who receive earnings	71	8.2
Composite Score SES Disadvantage	0.6	1.3
Geocoded Information*		
Dentists	1.5	2.1
Grocery stores	4.1	2.5
Churches	8.4	5.9

* Absolute numbers not adjusted for population size.

TABLE 3

Bivariate association between untreated decayed surfaces score and individual level predictors

Variable	Untreated Decayed (Mean ± se)	p-value*
Employment		0.00
Yes	28.1 ± 0.7	
No	31.6 ± 1.0	
Perception of mouth and teeth		0.00
Excellent	23.2 ± 2.9	
Very good	25.9 ± 1.7	
Good	25.1 ± 1.2	
Fair	29.9 ± 0.7	
Poor	36.3 ± 1.4	
Religiosity		0.04
Very religious	27.8 ± 1.0	
Fairly religious	31.0 ± 1.0	
Not too religious	30.2 ± 1.6	
Not religious at all	30.6 ± 1.2	
Social support		
Count on someone to give you reassurance		0.02
Yes	29.7 ± 0.8	
No	35.4 ± 2.2	
Oral hygiene		0.00
Good	27.9 ± 0.8	
Poor	33.0 ± 1.2	
Total sugar intake		0.02
<227 gr per day	29.0 ± 0.6	
>228 gr per day	32.2 ± 1.2	
Age		0.00
14–24	29.5 ± 1.1	
25–35	31.3 ± 0.9	
36–46	29.8 ± 1.6	
>= 47	25.5 ± 5.4	
Availability of dental services to you and your family		0.46
Excellent	28.0 ± 1.4	
Very good	31.2 ± 1.7	
Good	31.2 ± 1.7	
Fair	29.5 ± 1.3	
Bad	30.3 ± 2.1	
Very bad	32.6 ± 2.3	

* p-value is from ANOVA.

TABLE 4

Sequence of multilevel models for untreated decayed surfaces score

M1: Fully Unconditional	M2: Variance Components	M3: Intercept as Outcome	M4‡	
Individual Predictors¶				
Intercept	29.9 (0.7)*	16.0 (3.0)*	15.3 (3.1)*	16.5 (1.6)*
Age (Ref “14–24”)		2.2 (1.0)†	2.3 (1.0)†	2.2 (1.0)†
Employment (Ref “Yes”)		2.5 (1.0)†	2.4 (1.0)*	2.5 (1.0)†
Perceived oral health (Ref “E-G”)		6.2 (1.1)*	6.2 (1.0)*	6.2 (1.1)*
Oral hygiene status (Ref “Good”)		6.8 (1.1)*	6.9 (1.0)*	6.8 (1.1)*
Availability dental services (Ref “E-G”)		−1.9 (1.0)	−1.9 (1.0)	−2.0 (1.0)†
Total sugar intake (Ref “<227 gr/day”)		2.5 (1.0)†	2.6 (1.0)*	2.3 (1.0)*
Emotional support (Ref “Yes”)				6.2 (1.7)*
Neighborhood Predictors				
SES Score			−0.6 (0.6)	−0.4 (0.6)
Crime			1.3 (0.9)	0.8 (0.9)
Residential mobility			0.4 (0.8)	0.3 (0.7)
Churches			−2.7 (1.1)†	−2.7 (1.1)†
Grocery stores			2.1 (1.0)†	2.2 (1.0)†
Dentists			−0.7 (1.2)	−1.0 (1.1)
Random Estimates				
Between NCs variance	6.2†	6.8†	3.5	3.6
Within NCs variance	247.4*	214*	213.5*	211*

*p-value <0.001

†p-value <0.05

‡Statistical Model adjusted for the covariate of individual social support.

¶All individual predictors are dichotomized (Reference groups in parenthesis)