Community Dent Oral Epidemiol 2007; 35: 195–206

COMMUNITY DENTISTRY AND ORAL EPIDEMIOLOGY

The independent contribution of neighborhood disadvantage and individual-level socioeconomic position to self-reported oral health: a multilevel analysis

Gavin Turrell[1], Anne E. Sanders[2], Gary D. Slade[2], A. John Spencer[2] and Wagner Marcenes[3]

[1]School of Public Health, Queensland University of Technology, Brisbane, Australia, [2]Australian Research Centre for Population Oral Health (ARCPOH), The University of Adelaide, Adelaide, Australia, [3]Center for Oral Biometrics, Queen Mary's School of Medicine and Dentistry, University of London, London, UK

Turrell G, Sanders AE, Slade GD, Spencer AJ, Marcenes W. The independent contribution of neighborhood disadvantage and individual-level socioeconomic position to self-reported oral health: a multilevel analysis. Community Dent Oral Epidemiol 2007; 35: 195–206. © Blackwell Munksgaard 2007

Abstract – *Objectives:* To examine the association between neighborhood disadvantage and individual-level socioeconomic position (SEP) and self-reported oral health. *Methods:* A population-based cross-sectional study conducted in 2003 among males and females aged 43–57 years. The sample comprised 2915 individuals and 60 neighborhoods and was selected using a stratified two-stage cluster design. Data were collected using a mail survey (69.4% response rate). Neighborhood disadvantage was measured using a census-based composite index, and individual-level SEP was measured using education and household income. Oral health was indicated by self-reports of the impact of oral conditions on quality of life (0 = none or minor, 1 = severe), self-rated oral health (0 = excellent–good, 1 = fair/poor) and missing teeth (measured as a quantitative outcome). Data were analyzed using multilevel modeling. *Results:* After adjusting for age, sex, education, and household income, residents of socioeconomically disadvantaged neighborhoods were significantly more likely than those in more advantaged neighborhoods to indicate negative impacts of oral conditions on quality of life, to assess their oral health as fair or poor, and to report greater tooth loss. In addition, respondents with low levels of education and those from a low income household reported poorer oral health for each outcome independent of neighborhood disadvantage. *Conclusions:* The socioeconomic characteristics of neighborhoods are important for oral health over and above the socioeconomic characteristics of the people living in those neighborhoods. Policies and interventions to improve population oral health should be directed at the social, physical and infrastructural characteristics of places as well as individuals (i.e. the traditional target of intervention efforts).

Key words: Australia; health inequalities; multilevel analysis; neighborhoods; oral health; socioeconomic factors

Gavin Turrell, School of Public Health, Queensland University of Technology, Victoria Park Road, Kelvin Grove, Brisbane, Queensland, Australia, 4059
Tel: 61-7-38648285
Fax: 61-7-38643130
e-mail: g.turrell@qut.edu.au

Submitted 10 June 2005; accepted 27 March 2006

A large number of studies over many decades have examined the relationship between the socioeconomic characteristics of the neighborhood environment and health (1). With few exceptions, they have shown that mortality and morbidity are higher in disadvantaged neighbourhoods. Many of these studies conceptualized 'neighborhood disadvantage' as an area-level analog for individual-level socioeconomic position (SEP) and not as a factor that contributed to health in its own right (2, 3). A number of researchers criticized this perspective, and instead, promulgated the notion that the socioeconomic characteristics of where people live may influence health independently of

doi: 10.1111/j.1600-0528.2006.00311.x

individual socioeconomic characteristics (4–9). Residents of disadvantaged neighborhoods, it was suggested, were more likely to be exposed to poorer physical infrastructure, fewer health and community services, higher levels of crime, and lower stocks of social capital, and that these (and other) features of the neighborhood environment might directly affect health. This hypothesis represented a conceptual advance in arguing that health differences between rich and poor neighborhoods were due to both the social, physical, and economic characteristics of the neighborhoods *per se* (i.e. a context effect), and the socioeconomic characteristics of the people who lived in the neighborhoods (i.e. a composition effect). More crucially, this perspective highlighted the need for research to disentangle these two sources of neighborhood variation in health to establish and quantify the importance of the neighborhood environment as an independent determinant of health.

Until the mid-1990s, research into neighborhood effects on health was based primarily on ecological studies and the limitations of these are well documented (10–12). In brief, ecological studies typically compared the health profiles of advantaged and disadvantaged neighborhoods using data aggregated to a single geographic scale and hence were not able to indicate whether and to what extent health differences between the neighborhoods were due to compositional or contextual influences. Even though studies found significant differences between advantaged and disadvantaged neighborhoods in their general and oral health, this did not necessarily mean that the neighborhood environment *per se* was important in terms of influencing the health of residents. Ecological studies leave open the possibility that neighborhood variations in health are simply an artifact of varying population compositions (e.g. greater concentrations of poor people in poor areas), and unless this is taken into account, which ecologic studies cannot do, neighborhood- and individual-level sources of variation remain confounded (13). The question as to whether neighborhood context was an independent determinant of health over and above the characteristics of the people who lived in them remained unresolved.

From about the mid-1990s, research examining the neighborhood and health relationship has made increasing use of multilevel analytic methods, which unlike ecologic approaches, allow for the partitioning of neighborhood and individual sources of variation (i.e. between contextual and composition effects). The methodological and statistical advantages of multilevel modeling have now been extensively discussed in the health literature (14–16), as have the limitations of the technique (17). Multilevel research conducted to date has shown that living in a socioeconomically disadvantaged neighborhood is associated with higher mortality (18, 19), poorer self-rated health (20–22), lower levels of physical activity (23, 24), higher smoking prevalence (25, 26) and higher body mass (27) even after taking account of the socioeconomic characteristics of the people living in the neighborhood.

To date, no published study has employed multilevel analytic methods to investigate links between neighborhood disadvantage, individual-level SEP and oral health. A multilevel perspective, however, has recently been advocated as a way of advancing understanding about socioeconomic inequalities in oral health, and by extension, improving attempts to reduce the inequalities (28). In this present paper, we use multilevel analytic methods to examine the relationships between neighborhood socioeconomic disadvantage and oral health in an urban adult population. Our aim was to assess whether and to what extent self-reported oral health is related to the socioeconomic characteristics of neighborhoods after adjusting for individual-level demographic and socioeconomic factors. Based on the results of studies from the general health literature, we hypothesized that living in a socioeconomically disadvantaged neighborhood is associated with poorer oral health independent of individual-level factors. If confirmed, this association will indicate that urban neighborhoods are differentiated on the basis of environmental factors important for oral health, and that disadvantaged neighborhoods are less conducive to the attainment and maintenance of good oral health. Confirmation of the hypothesis will also suggest that policies and programs to improve population oral health and reduce health inequalities should focus on places as well as people.

Methods

The University of Adelaide Human Ethics and Research Committee approved the study (no. H80-2002).

Geographic scope

This paper is based on data collected as part of the Adelaide Small Area Dental Study (ASADS), a cross-sectional study of oral health conducted in 2003. The target population for ASADS comprised people residing within the Adelaide Statistical Division (ASD), an area covering 1826.9 km^2 that includes Adelaide (the capital city of the State of South Australia) and its surrounding metropolitan areas. In 2001, the ASD comprised 122 contiguous postcodes whose resident populations ranged from 298 to 35 446 [mean 8449, standard deviation (SD) 6080].

Sample design

We used a multi-stage probability sampling design to select a stratified random sample of postcodes, and from within each postcode, a random sample of people aged 43–57 years. Postcodes are geographic regions used by Australia Post for the purpose of delivering mail and they are closely equivalent to local suburbs, hence they are likely to have meaning and significance for their residents: for this reason, we hereafter use the term 'neighborhood' to refer to postcode/suburb as this is more consistent with international parlance.

We sampled adults aged 43–57 years as this age range represents the baby-boom cohort born in the economically prosperous period from 1946 to 1960 following World War II. This extremely large cohort is important to demographers and health service planners in general, and this is especially the case for dental care planning because the cohort retains more teeth throughout life than the preceding generations. Yet unlike younger adults, this cohort was not exposed to fluoridated water supplies during the period of enamel development or early posteruptive maturation. Moreover, this 'middle-aged' cohort constitutes the main driving force behind the rising demand for dental care in Australia. Restricting the age range also limited the potential confounding effect of age on the oral health outcomes.

The sampling of neighborhoods, and residents within neighborhoods, was guided by Cohen's sample-size algorithm for two-level study designs (29). Neighborhoods were selected in four stages. First, from all 122 neighborhoods in Adelaide, we excluded nine that contained small populations (i.e. <600 people). Secondly, we then assigned the remaining 113 neighborhoods a socioeconomic score using the Australian Bureau of Statistics' Index of Relative Socioeconomic Disadvantage (IRSD) (30). IRSD scores for areas are based on Census data and reflect area-level attributes such as the proportion of low-income families and individuals with limited educational attainment, the occupancy of public sector housing, the unemployment rate, and the extent of the workforce in relatively unskilled occupations (among others). IRSD scores are standardized across Australia to a mean of 1000 and a standard deviation of 100, with lower values signifying more socioeconomically disadvantaged areas. Thirdly, the 113 neighborhoods were subsequently ranked by their IRSD score to form a distribution that was divided into deciles. Fourthly, six neighborhoods were selected from each decile using systematic without replacement probability proportional-to-size sampling (with size being defined by population). The socioeconomic characteristics of the 60 sampled neighborhoods are presented in Table 1: as would be predicted from the stratification process, the neighborhoods differ markedly on a range of key socioeconomic indicators.

For each of the sampled neighborhoods we obtained information about the name, sex, age-group and home address of all people registered to vote with the Australian Electoral Commission. In Australia, voting is compulsory for persons aged ≥18 years, so the electoral roll provides a near-complete coverage of the resident population. From each of the 60 neighborhoods, we selected 70 individuals using simple random sampling.

Data collection

Data were collected between September and December 2003 using a self-completed survey that was administered using methods described by Dillman (31). A primary approach letter was mailed one week in advance of the survey advising individuals of the study and encouraging their participation. This was followed 7 days later with

Table 1. Socioeconomic profile of the sampled neighborhoods [mean (SD)]

Neighborhood number[a]	% Housing authority dwellings	Unemployment rate (%)	% Blue Collar Labor force
1–6	60.4 (10.2)	15.1 (4.0)	17.1 (3.7)
7–12	34.1 (19.4)	11.9 (1.0)	15.3 (3.1)
13–18	26.2 (8.9)	9.9 (0.53)	10.3 (2.6)
19–24	25.0 (9.7)	8.4 (0.42)	10.7 (1.2)
25–30	25.5 (12.7)	7.7 (0.32)	9.6 (2.0)
31–36	28.2 (25.1)	6.6 (0.80)	8.0 (1.9)
37–42	21.0 (12.8)	5.8 (0.9)	6.7 (0.82)
43–48	13.3 (14.5)	4.9 (0.72)	6.9 (2.3)
49–54	5.2 (3.8)	4.9 (0.60)	6.2 (1.6)
55–60	4.2 (2.7)	5.2 (1.1)	4.3 (1.1)

[a]Neighborhoods 1–6 are the 10% most disadvantaged.

an envelope containing a cover letter, a self-administered 16-page survey, and a pre-addressed prepaid reply envelope. A reminder post card was sent to nonrespondents after 14 days, followed by a replacement survey with cover letter to non-respondents after a further 14 days. Up to two more reminders were sent – one at 6 weeks and a final reminder 8 weeks after mailing the initial survey. Each round of mailings was accompanied with a differently worded cover letter and was personalized using the sampled person's name as recorded on the Electoral Roll. A total of 2915 usable surveys were returned, with a response rate that ranged from 61.7% among neighborhoods in the most disadvantaged decile to 77.4% in the least disadvantage decile (overall response rate of 69.4%). This equated to an average of 48.6 respondents per neighborhood (SD 5.7, range 33–61).

Socioeconomic measures

Neighborhood disadvantage

Each neighborhood was assigned a socioeconomic disadvantage score based on the IRSD (described above), and across the 60 neighborhoods the IRSD scores ranged from 767.8 to 1136.0 (mean 1000.8, SD 86.8), with lower scores indicating greater disadvantage.

Education

The survey asked respondents whether they had attained further education since leaving school, and if so, the highest qualification completed. Respondent's education was subsequently coded as (i) bachelor degree or higher (the latter included postgraduate diploma, masters degree, or doctorate) (ii) diploma (associate or undergraduate), (iii) vocational (trade or business certificate, or apprenticeship), (iv) no postschool qualifications, and (v) other (not easily classifiable). In addition, a small number of respondents failed to supply details about their educational qualifications and they were classified with 'unknown' education.

Household income

Respondents were asked to estimate the total pretax income in their household. Nine categories of response were provided which subsequently were recoded into four categories for analysis: (i) less than AUS$20 799, (ii) $20 800–36 399, (iii) $36 400–51 999, and (iv) $52 000 or more. Households in categories (i) and (ii) received incomes at or below the Australian average as at 2000 (32). Respondents, who either refused to provide information about their household income or indicated that they did not know, were classified into a fifth 'unknown' income category.

Oral health measures

Oral Health Impact Profile

The measure (33) evaluates the adverse impacts of oral conditions on quality of life. The scale was based on the World Health Organization's 1980 International Classification of Impairment, Disability and Handicap that was adapted for oral health in 1988 by Locker (34). We used the 14-item short-form (OHIP-14) that was subsequently derived and validated by Slade (35). Two items represent each of the scale's seven theoretical dimensions of functional limitation, physical pain, psychological discomfort, physical disability, psychological disability, social disability and handicap. The scale has been translated into several languages and has been widely used in a range of studies including randomized clinical trials and more recently in international comparative population surveys (36, 37). The OHIP-14 asks about the frequency of adverse impacts caused by oral conditions during the previous 12 months and responses are given on a five-point ordinal scale ranging from never (coded 0) to very often (coded 4). As a summary statistic, we used the percentage of people reporting one or more items 'fairly often' or 'very often'.

Global self-assessment of oral health

This was examined with a single item that asked respondents to rate their overall oral health on a five-point scale ranging from 'excellent' to 'poor'; these responses were divided into two groups with the reference category comprising respondents who indicated 'fair' or 'poor'. This global measure is a bidirectional indicator, capable of measuring both favorable and unfavorable oral health status. The item has been used widely in surveys including the National Dental Telephone Interview Survey in Australia (38), as well as in the International Collaborative Study of Oral Health Outcomes (39) and the National Health and Nutrition Examination Survey in the United States (40).

Missing teeth

Respondents were asked whether they had any of their own natural teeth (yes/no) and those responding affirmatively were subsequently asked to report the number of natural teeth in each arch. These two questions were used to create a continuous variable representing the number of teeth that were missing for any reason, with values ranging from zero (complete dentition, $n = 248$, 8.7%) to 32 (edentulous, $n = 86$, 3.01%). Previous research has shown that self-assessment of number of natural teeth yields valid estimates (41, 42).

Analysis

Multilevel modeling was used to assess whether neighborhood disadvantage was related to OHIP-14, self-rated oral health and missing teeth after controlling for individual-level demographic and socioeconomic characteristics. The data were analyzed using MLwiN version 2.0 (43). As OHIP-14 and self-rated oral health were dichotomous outcomes, they were examined using a binomial logit–link model with the predictive–penalized quasi-likelihood procedure and second-order linearization using the iterative generalized least squares algorithm (44). Three models were specified for each outcome. First, a null model, comprising individuals (level 1) nested in neighborhoods (level 2) with no area- or person-level variables in the fixed part of the model. Substantive interest for the null model focuses on the neighborhood random term, which if significant (indicated using Wald chi-square), suggests between-neighborhood variation in oral health. The null model was subsequently extended to include person-level fixed effects for age in years (mean centered), sex, education and household income (model 2), and then neighborhood disadvantage (model 3). The results are presented as odds ratios and their 95% confidence intervals (CI). For each logistic model the intra-class correlation (ICC) was calculated using an approach described by Hox (45). The ICC estimates the percentage of total variance in oral health that was between neighborhoods: the remainder is between-individual variation. As the variable measuring missing teeth was quantitative, this was examined using a two-level random intercept variance components model. Again, three models were specified (as described above) and the results are expressed as parameter estimates that reflect the absolute difference in missing teeth relative to a reference group, and their 95% CI. For each model, an ICC was calculated directly by dividing the between neighborhood variance by the total variance, and is interpreted as the proportion of total residual variation that is due to differences between neighborhoods (43, 46). For all three oral health outcomes, joint chi-squared tests were performed on the fixed effects (i.e. education, income and neighborhood disadvantage) to evaluate their overall significance of contribution to model fit. Further, for each outcome we also included country of birth in models 2 and 3, and excluded respondents with missing values for one or more explanatory variables. This did not meaningfully alter interpretations about other effects in the models; consequently, these findings are not included in the tabulated results.

Results

Table 2 presents descriptive statistics for each of the measures used in this analysis. Of the 2915 respondents, missing data were recorded for OHIP-14 ($n = 31$), self-rated oral health ($n = 39$), and missing teeth ($n = 55$), resulting in final samples of $n = 2884$, $n = 2876$, and $n = 2860$ for these outcomes, respectively.

Table 2. Descriptive statistics for the sociodemographic variables and the measures of self-reported oral health

$N = 2915$	n	%
Sex		
Male	1332	45.7
Female	1583	54.3
Education (highest level attained)		
Bachelor degree or higher	579	19.9
Diploma	317	10.9
Vocational	660	22.6
No postschool qualifications	1131	38.8
Other (not easily classifiable)	157	5.4
Missing	71	2.4
Household income		
Aus$52 000 or more	1323	45.4
Aus$36 400–51 999	507	17.4
Aus$20 800–36 399	438	15.0
Aus$20 799 or less	364	12.5
Do not know/missing	283	9.7
Oral Health Impact Profile (OHIP-14)[a]		
Nil or minor impact on quality of life	2463	85.4
Severe impact on quality of life	421	14.6
Self-reported oral health[b]		
Excellent/very good/good	2307	80.2
Fair/poor	569	19.8
Missing teeth: mean (SD), median[c]	6.7 (6.7)	5.0
Neighborhood disadvantage: mean (SD), median[d]	1000.8 (86.8)	998.8
Age (years): mean (SD), median	50.1 (4.2)	50.0

[a]Excludes 31 cases that were classified as missing on OHIP-14.
[b]Excludes 39 cases that were classified as missing on the self-reported oral health variable.
[c]Excludes 55 cases that were classified as missing on the 'Missing teeth' variable.
[d]For analysis, neighborhood disadvantage was categorized into deciles.

Table 3 presents the association between neighborhood disadvantage and individual-level socioeconomic factors and OHIP-14. For the null model (model 1), there was significant neighborhood variation in the odds of reporting that oral conditions impacted negatively on quality of life ($P = 0.036$), although only 3.2% (ICC) of the variability occurred between neighborhoods. There was no longer any significant between-neighborhood variation for OHIP-14, however, after adjustment for within-neighborhood clustering based on education and household income (Model 2). Education was not associated with OHIP-14, whereas household income showed a graded relationship, with the greatest negative impact of oral conditions being reported by those from low-income households. Independent of education and household income, there was a significant association between neighborhood disadvantage and OHIP-14, with the poorest health being reported by residents of neighborhoods in the more disadvantaged deciles (model 3).

Table 4 presents the association between neighborhood disadvantage and individual-level socioeconomic factors and self-reported oral health. The null model (model 1) shows statistically significant variation at the neighborhood level ($P = 0.004$): the odds of reporting fair/poor oral health were different across the neighborhoods. There was no significant neighborhood variation however after adjustment for education and household income (model 2) and variation was further reduced after inclusion of the neighborhood disadvantage variable (model 3). Education level was not associated

Table 3. Neighborhood and individual-level effects on the Oral Health Impact Profile (OHIP-14) measure[a, b]

Neighborhoods = 60 Individuals = 2884	Model 1 (null model)	Model 2 (plus education & household income)[c]	Model 3 (plus neighborhood disadvantage)[c]
Constant	−1.80	−2.34	−2.59
Fixed effects		OR (95% CI)	OR (95% CI)
Education[d]			
Bachelor degree or higher		–	–
Diploma		0.99 (0.63–1.54)	0.94 (0.60–1.47)
Vocational		0.90 (0.62–1.31)	0.81 (0.55–1.18)
No postschool qualifications		1.20 (0.86–1.67)	1.06 (0.76–1.49)
Other (not easily classifiable)		1.02 (0.60–1.73)	0.92 (0.54–1.57)
Missing		2.49 (1.27–4.86)	2.12 (1.08–4.18)
Household income[d]			
Aus$52 000 or more		–	–
Aus$36 400–51 999		1.69 (1.22–2.34)	1.54 (1.11–2.15)
Aus$20 800–36 399		2.11 (1.52–2.93)	1.88 (1.35–2.63)
Aus$20 799 or less		5.49 (4.04–7.47)	4.68 (3.40–6.44)
Missing/do not know		1.60 (1.07–2.39)	1.50 (1.00–2.25)
Neighborhood disadvantage[d]			
Decile 10 (least disadvantaged)			–
Decile 9			1.32 (0.76–2.30)
Decile 8			1.18 (0.67–2.07)
Decile 7			1.33 (0.77–2.31)
Decile 6			1.31 (0.76–2.29)
Decile 5			1.72 (1.00–2.96)
Decile 4			1.81 (1.06–3.10)
Decile 3			1.67 (0.97–2.87)
Decile 2			1.91 (1.12–3.27)
Decile 1 (most disadvantaged)			2.17 (1.27–3.71)
Level 2 (neighborhood) variance[e]	0.107 (0.051)	0.00 (0.00)[f]	0.00 (0.00)
Intraclass correlation (%)	3.2%	0.0	0.00
Wald test of level 2 variance	4.42	–[g]	–
P-value	0.036	–	–

[a]The models estimate the odds of reporting one or more impacts often or very often on the OHIP-14 measure.
[b]Excludes 31 cases that were classified as missing on the OHIP-14 measure.
[c]Also adjusted for age and sex but results not shown.
[d]Model 2: Joint chi-square *P*-values for education ($P = 0.899$) and income ($P \leq 0.01$). Corresponding *P*-values for Model 3: education ($P = 0.657$), income ($P \leq 0.01$) and neighborhood disadvantage ($P = 0.044$).
[e]Variance estimate (standard error).
[f]See Snijders and Bosker (46) for a discussion of why level 2 variance can be estimated as zero (p. 57).
[g]It was not possible to perform a Wald test as the level 2 (neighborhood) variance was estimated as zero.

Table 4. Neighborhood and individual-level effects on self-rated oral health[a, b]

Neighborhoods = 60 Individuals = 2876	Model 1 (null model)	Model 2 (plus education and household income)[c]	Model 3 (plus neighborhood disadvantage)[c]
Constant	−1.43	−2.13	−2.19
Fixed effects [OR (95% CI)]			
Education[d]			
Bachelor degree or higher		–	–
Diploma		1.02 (0.69–1.50)	1.00 (0.68–1.48)
Vocational		0.92 (0.67–1.27)	0.87 (0.62–1.20)
No postschool qualifications		1.30 (0.97–1.74)	1.20 (0.89–1.61)
Other (not easily classifiable)		1.05 (0.65–1.70)	0.99 (0.61–1.60)
Missing		1.63 (0.88–3.03)	1.48 (0.79–2.76)
Household income[d]			
Aus$52 000 or more		–	–
Aus$36 400–51 999		1.65 (1.25–2.18)	1.53 (1.15–2.03)
Aus$20 800–36 399		2.13 (1.60–2.83)	1.93 (1.45–2.57)
Aus$20 799 or less		3.85 (2.89–5.13)	3.32 (2.47–4.45)
Missing/do not know		1.21 (0.84–1.76)	1.16 (0.80–1.68)
Neighborhood disadvantage[d]			
Decile 10 (least disadvantaged)			–
Decile 9			0.74 (0.45–1.20)
Decile 8			0.94 (0.59–1.49)
Decile 7			1.10 (0.70–1.73)
Decile 6			0.84 (0.52–1.36)
Decile 5			1.54 (0.99–2.39)
Decile 4			1.10 (0.69–1.73)
Decile 3			1.61 (1.04–2.50)
Decile 2			1.80 (1.16–2.80)
Decile 1 (most disadvantaged)			1.83 (1.17–2.86)
Level 2 (neighborhood) variance[e]	0.151 (0.053)	0.047 (0.034)	0.00 (0.00)[f]
Intraclass correlation (%)	4.4%	1.4%	0.00
Wald test of level 2 variance	8.23	1.91	–[g]
P-value	0.004	0.167	–

[a]The models estimate the odds of reporting fair/poor oral health.
[b]Excludes 39 cases that were classified as missing on the self-rated oral health variable.
[c]Also adjusted for age and sex but results not shown.
[d]Model 2: Joint chi-square *P*-values for education ($P = 0.651$) and income ($P \leq 0.01$). Corresponding *P*-values for Model 3: education ($P = 0.924$), income ($P \leq 0.01$) and neighborhood disadvantage ($P = 0.317$).
[e]Variance estimate (standard error).
[f]See Snijders and Bosker (46) for a discussion of why level 2 random effects variance can be estimated as zero (p. 57).
[g]It was not possible to perform a Wald test as the level 2 (neighborhood) variance was estimated as zero.

with self-rated oral health, although a significant relationship was found for household income, with residents of low income households being more likely to report fair/poor oral health. Residents of socioeconomically disadvantaged neighborhoods were more likely to report fair/poor oral health after adjustment for education and household income (model 3).

Table 5 presents the results for missing teeth. For the null model (model 1) the neighborhood random term was significant ($P \leq 0.01$) indicating that the average number of missing teeth was not constant across the 60 neighborhoods. Of the total variability, 5.66% occurred between neighborhoods and 94.34% between individuals. Adjustment for compositional clustering based on education and household income reduced the neighborhood level random term from 2.58 to 1.26 (model 2) although it remained statistically significant ($P < 0.001$). Further adjustment for neighborhood disadvantage, however, resulted in no statistically significant variation being observed between neighborhoods in missing teeth (model 3). Both education and household income were significantly associated with missing teeth. Respondents from low income households for example, had an average of 3.45 (95% CI 2.67–4.24) fewer teeth than their counterparts from high income households (model 3). Neighborhood disadvantage was related to missing teeth after adjusting for education and household income, with higher levels of edentulism being reported by respondents from socioeconomically deprived neighbourhoods.

Table 5. Neighborhood and individual-level effects on missing teeth[a]

Neighborhoods = 60 Individuals = 2860	Model 1 (null model)	Model 2 (plus education and household income)[b]	Model 3 (plus neighborhood disadvantage)[b]
Constant	6.75	4.74	3.73
Fixed effects [β (95% CI)[c]]			
Education[d]			
Bachelor degree or higher	–	–	–
Diploma		−0.04 (−0.90 to 0.82)	−0.08 (−0.94 to 0.79)
Vocational		1.34 (0.61 to 2.08)	1.21 (0.48 to 1.95)
No postschool qualifications		1.53 (0.85 to 2.21)	1.39 (0.71 to 2.07)
Other (not easily classifiable)		0.99 (−0.14 to 2.12)	0.91 (−0.22 to 2.04)
Missing		2.75 (1.15 to 4.35)	2.55 (0.94 to 4.15)
Household income[d]			
Aus$52 000 or more		–	–
Aus$36 400–51 999		1.24 (0.58 to 1.90)	1.06 (0.40 to 1.72)
Aus$20 800–36 399		1.60 (0.89 to 2.31)	1.36 (0.64, 2.07)
Aus$20 799 or less		3.81 (3.04 to 4.58)	3.45 (2.67 to 4.24)
Missing/do not know		1.63 (0.79 to 2.47)	1.53 (0.70 to 2.37)
Neighborhood disadvantage[d]			
Decile 10 (least disadvantaged)			–
Decile 9			0.31 (−0.89 to 1.51)
Decile 8			0.71 (−0.49 to 1.91)
Decile 7			0.65 (−0.55 to 1.85)
Decile 6			0.49 (−0.73 to 1.71)
Decile 5			1.43 (0.19 to 2.67)
Decile 4			1.55 (0.31 to 2.80)
Decile 3			2.16 (0.91 to 3.41)
Decile 2			1.81 (0.56 to 3.06)
Decile 1 (most disadvantaged)			3.56 (2.27 to 4.85)
Level 2 (neighborhood) variance[e]	2.58 (0.637)	1.26 (0.378)	0.371 (0.215)
Intraclass correlation (%)	5.66	3.19	0.96
Wald test of level 2 variance	16.36	11.11	2.98
P-value	≤0.01	0.0008	0.084

[a]Excludes 55 cases that were classified as missing on the 'Missing teeth' variable.
[b]Also adjusted for age and sex but results not shown.
[c]Coefficients (β) with confidence intervals that are not inclusive of zero are significantly different from the reference group at the 0.05 level. Example: In model 2, for those from low income households (≤$20 799) we can be 95% confident that the interval 3.04–4.58 includes the 'true' difference in missing teeth for this group relative to the reference group ($52 000 or more).
[d]Model 2: Joint chi-square P-values for education ($P = 0.003$) and income ($P \leq 0.01$). Corresponding P-values for model 3: education ($P = 0.008$), income ($P \leq 0.01$) and neighborhood disadvantage ($P = 0.003$).
[e]Variance estimate (standard error).

Discussion

The results of this study showed that the socioeconomic characteristics of neighborhoods was associated with self-reported oral health independent of the socioeconomic characteristics of the people living in those neighborhoods. Specifically, residents of disadvantaged neighborhoods were more likely to rate their oral health as fair or poor, to report that they had fewer teeth, and to indicate that oral health conditions impacted negatively on quality of life. This effect of neighborhood disadvantage persisted after we adjusted for the residents' education levels and for income differences between households in each area. These results corroborated findings from earlier studies reporting the importance of neighborhood- and individual-level factors for oral health (3, 47–49). These earlier studies however were limited by their use of aggregate designs and single-level statistical models that made it impossible to know whether the apparent neighborhood effects on oral health were real, or whether they were due to an artifact of varying population compositions (e.g. greater concentrations of poor people in disadvantaged neighborhoods). In short, earlier approaches were not able to distinguish the 'difference a place makes' (context) from 'what's in a place' (composition) (13).

Study limitations

A number of methodologic and analytic issues may affect how we interpret and understand this study's findings. First, the between-neighborhood variance for models 2 and 3 for OHIP-14 and model 3 for self-rated oral health were estimated as zero. At first appearance, this suggests that neighborhoods do not influence self-reports of oral health, although other statistical explanations exist, and the topic is debated in the broader multilevel literature. One suggestion is that a 'null finding' of near-zero neighborhood variance might be due to the study's statistical power to detect variance components. In multilevel analysis of neighborhood effects, power is influenced by the number of neighborhoods sampled, the number of residents per neighborhood, and the ICC (46, 50). Crucially, the relativities among these three sampling elements has a differential affect on power depending on whether one is interested in estimating random or fixed effects. A given sample size for instance may be adequate to estimate the fixed (i.e. average) effect of neighborhood disadvantage on oral health, but inadequate to reliably estimate the between-neighborhood variance. In examining this issue, Diez Roux (50) suggests that 'one should be wary of concluding that associations between neighborhood characteristics and individual-level variables are not worth examining because in a given study the variance of the random neighborhood effect is not statistically significant' (p. 1954). In a more technical discussion, Snijders and Bosker (46) note that when variance estimates are very small (possibly due the abovementioned sampling issues) some computer programs report the random parameter and its standard error as zero (which occurred in this present study); however, 'this does not mean that the data imply absolute certainty that the population value of [the variance estimate] is equal to 0' (p. 57). Exact values for very small variance estimates can be derived using more advanced techniques such as Markov Chain Monte Carlo (MCMC) simulations.

Second, as with most multilevel studies (9, 51) our choice of area-unit (i.e. postcode) was made for reasons of sampling and analytic convenience rather than being underpinned by an explicit theory linking neighborhood disadvantage and oral health; hence associations among these variables are likely to be underestimated. Had it been possible to derive an area-unit based on peoples' actual reports of what in their minds constituted their local neighborhood and what was socially and culturally meaningful in terms of their health and behaviour, then we might reasonably have expected to observe stronger neighborhood effects on oral health.

Third, our finding of an association between neighborhood disadvantage and oral health might be confounded by individual-level socioeconomic factors not included in the models. However, we included two of the most widely used indicators of a person's socioeconomic characteristics (i.e. education and income) and given the correlation among socioeconomic measures (52) it is likely that these two socioeconomic indicators would capture some of the unmeasured influences of other socioeconomic factors excluded from the models. Alternatively, it may be that the inclusion of individual-level measures of SEP resulted in 'over-adjustment' which argues for the possibility of an even stronger contextual effect on oral health than was observed in this study. If education and household income represent part of the pathway via which neighborhood disadvantage influences the oral health status of the residents of the areas, then simultaneously modeling individual-level socioeconomic variables may have inappropriately attenuated the variation that was more correctly attributable to neighborhood disadvantage (50).

Fourth, we relied on arbitrary thresholds that classified 15–20% of respondents as experiencing relatively poor health outcomes for oral health related quality of life and subjective oral health. We settled on these thresholds in part to generate associations with outcomes of approximately equal prevalence, thereby affording similar statistical power to detect compositional and contextual influences for each outcome.

Finally, the findings of this study are based on a research design that achieved a moderate individual-level response rate of 69.4%, and a response rate that followed an inverse association across the deciles of neighborhood disadvantage. We thus need to consider the likely bias attributable to nonresponse, and how this might affect this study's inferences to the wider population. Previous studies show that persons from socioeconomically disadvantaged backgrounds (53), and residents of more deprived neighborhoods (24), are least likely to respond to, or participate in, survey research. As a result, population-based samples typically under-represent the most disadvantaged and over-represent the advantaged, the likely consequence of which is a socioeconomically truncated sample resulting in an underestimation of the magnitude of socioeconomic variability in the oral health outcomes being investigated. The neighborhood- and individual-level socioeconomic differences in oral health reported in this paper therefore, while significant, are likely to be an underestimate of the 'true' magnitude of socioeconomic differences in the population.

Possible reasons for the study's findings

Why did socioeconomically disadvantaged neighborhoods have a poorer oral health profile than more advantaged neighborhoods even though we adjusted for compositional clustering by education and household income? Although we can only speculate at this point, a number of possible reasons present themselves. Dental practices or shops selling healthy foods may be disproportionately located in socioeconomically advantaged areas, resulting in residents of disadvantaged areas having to travel further to see a dentist or buy healthy food. Moreover, the inconvenience and additional costs and time associated with this possibly act as disincentives to accessing these services and facilities. These difficulties may be further compounded by disadvantaged areas being less adequately served by public transport, and/or that residents of these areas may have more restricted access to private transport.

Social capital may contribute to oral health differences between areas (54). Social capital has been defined as 'features of social organization such as trust, norms, and networks that can improve the efficiency of society by facilitating coordinated actions' (55). Thus social capital is a characteristic of a neighborhood's overarching social fabric and is not reducible to individuals. The biological plausibility of social capital as a determinant of general health (and by extension oral health) has been suggested to result from at least three processes (56). First, neighborhoods with high levels of social capital may function to promote and protect psychosocial health, with some forms of capital resulting in more cohesive neighborhoods characterised by high levels of trust, reciprocity, and mutual concern for others. Living in a cohesive neighborhood therefore, may be conducive to less fear, stress and anxiety (57–59) and hence possibly lower levels of periodontal disease among its residents (60). Second, socioeconomically advantaged neighborhoods often have more extensive 'webs' of social networks, organizations, and groups, and their residents are more likely participate in civic activity and the political process (56). Such neighborhoods may be more able to secure health-promoting resources such as recreation facilities, public transport, or improved educational opportunities, whilst also collectively mobilizing against potentially health-damaging activities such as government cut-backs to essential services or private sector initiatives such as the establishment of a fast-food outlet. Third, neighborhoods with high levels of social capital are possibly characterised by shared norms and a general consensus about what constitutes 'appropriate' practices as these pertain to the benefit of individuals and the neighborhood as a whole. Some have proposed that this 'moral' dimension of social capital might influence behaviour in ways that produce positive health outcomes (61). Neighborhoods that value health for example, may favorably sanction some processes (e.g. regular dental check-ups) while negatively sanctioning behaviours that are inconsistent with this value, such as smoking in public places. The flip-side of this position is that neighborhoods with low levels of social capital and a less-binding moral order may be more likely to tolerate health damaging behaviours and be less likely to take civic action in response to these practices (62).

Finally, we need to briefly discuss our finding of an association between education, household income, and oral health, and in particular, evidence showing that lower educated respondents and those from low income households had more missing teeth, were more likely to rate their overall oral health as fair or poor, and were more likely to indicate that oral health conditions impacted negatively on quality of life. Arguably, education and household income represent different socioeconomic pathways to oral health. Education-level for example, may influence the acquisition of knowledge about appropriate oral health practices, or facilitate or constrain ones ability to understand information communicated in oral health education and promotion messages or on dental-product labels. Household income is likely to reflect the availability of economic and material resources, and hence influence oral health by making dental services more or less affordable and accessible.

Conclusion

This first known multilevel study of oral health found strong evidence that a range of self-reported conditions were significantly associated with both neighborhood disadvantage and the individual socioeconomic characteristics of the residents of the neighborhood. Our findings suggest that policies and interventions to improve oral health need to be directed at both individuals and the neighbourhood contexts in which they live.

Acknowledgments

The study was supported by a project grant from the National Health and Medical Research Council (no. 250315). Dr Turrell is supported by a National Health and Medical Research Council/National Heart Foundation Career Development Award (CR 01B 0502).

References

1. Kawachi I, Berkman LF. Neighborhoods and health. New York: Oxford University Press; 2003.
2. Macintyre S, Maciver S, Sooman A. Area, class and health: should we be focusing on places or people? J Soc Pol 1993;22:213–34.
3. Locker D. Measuring social inequality in dental health services research: individual, household and area-based measures. Community Dent Health 1993;10:139–50.
4. Kaplan G. People and places – contrasting perspectives on the association between social class and health. Int J Health Serv 1996;26:507–19.
5. Kearns RA. Place and health: towards a reformed medical geography. Professional Geographer 1993;45:139–47.
6. Jones K, Moon G. Medical geography: taking space seriously. Prog Hum Geography 1993;17:515–24.
7. Macintyre S, Ellaway A. Ecological approaches: rediscovering the role of the physical and social environment. In: Berkman LF, Kawachi I, editors. Social epidemiology. New York: Oxford University Press; 2000. p. 332–48.
8. Robert SA. Socioeconomic position and health: the independent contribution of community socioeconomic context. Annu Rev Sociol 1999;25:489–516.
9. Curtis S, Jones IR. Is there a place for geography in the analysis of health inequality? Sociol Health Illness 1998;20:645–72.
10. Greenland S. Ecologic versus individual-level sources of bias in ecologic estimates of contextual health effects. Int J Epidemiol 2001;30:1343–50.
11. Milyo J, Mellor JM. On the importance of age-adjustment methods in ecological studies of social determinants of mortality. Health Serv Res 2003;38:1781–90.
12. Diez-Roux AV. Investigating neighbourhood and area effects on health. Am J Public Health 2001;91:1783–89.
13. Subramanian SV, Duncan C, Jones K. Multilevel perspectives on modeling census data. Environ Plan A 2001;33:399–417.
14. Diez-Roux AV. Multilevel analysis in public health research. Annu Rev Public Health 2000;21:193–221.
15. Greenland S. A review of multilevel theory for ecologic analyses. Stat Med 2002;21:389–95.
16. Subramanian SV. The relevance of multilevel statistical methods for identifying causal neighbourhood effects. Soc Sci Med 2004;58:1961–7.
17. Oakes M. The (mis) estimation of neighbourhood effects: causal inference for a practicable social epidemiology. Soc Sci Med 2004;58:1929–1952.
18. Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. J Epidemiol Community Health 2001;55:111–22.
19. Marinacci C, Spadea T, Biggerie A, Demaria M, Caiazzo A, Costa G. The role of individual and contextual socioeconomic characteristics on mortality: analysis of time variations in a city of north west Italy. J Epidemiol Community Health 2004;58:199–207.
20. Stafford M, Marmot M. Neighbourhood deprivation and health: does it affect us all equally? Int J Epidemiol 2003;32:357–66.
21. Subramanian S, Kawachi I, Kennedy B. Does the state you live in make a difference? Multilevel analysis of self-rated health in the US. Soc Sci Med 2001;53:9–19.
22. Malstrom M, Sundquist J, Johansson S. Neighbourhood environment and self-reported health status: a multilevel analysis. Am J Public Health 1999;89:1181–6.
23. Yen IH, Kaplan GA. Poverty area residence and changes in physical activity level: evidence from the Alameda County Study. Am J Public Health 1998;88:1709–12.
24. Kavanagh AM, Goller JL, King T, Jolley D, Crawford D, Turrell G. Urban area disadvantage and physical activity: a multilevel study in Melbourne, Australia. J Epidemiol Community Health 2005;59:934–940.
25. Reijneveld S. The impact of individual and area characteristics on urban socioeconomic differences in health and smoking. Int J Epidemiol 1998;27:33–40.
26. Reijneveld S. Neighbourhood socioeconomic context and self reported health and smoking: a secondary analysis of data on seven cities. J Epidemiol Community Health 2002;56:935–42.
27. King T, Kavanagh AM, Jolley D, Turrell G, Crawford D. Weight and place: a multilevel cross-sectional survey of area-level social disadvantage and overweight/obesity in Australia. Int J Obes 2006;30:281–7.
28. Newton JT, Bower EJ. The social determinants of oral health: new approaches to conceptualizing and researching complex causal networks. Community Dent Oral Epidemiol 2005;33:25–34.
29. Cohen MP. Determining sample sizes for surveys with data analyzed by hierarchical linear models. J Official Stat 1998;14:267–275.
30. Australian Bureau of Statistics. Socioeconomic indexes for areas, 1996. Cat. No. 2039.0. Canberra: Australian Government Publishing Service; 1998.
31. Dillman DA. Mail and internet surveys: the tailored designed method. 2nd edn. New York: John Wiley & Sons Inc; 2000.
32. Australian Bureau of Statistics. Income distribution 1999–2000. Cat. No. 6523.0. Canberra: Australian Government Publishing Service; 2001.

33. Slade GD, Spencer AJ. Development and evaluation of the Oral Health Impact Profile. Community Dent Health 1994;11:3–11.
34. Locker D. Measuring oral health: a conceptual framework. Community Dent Health 1988;5:3–18.
35. Slade GD. Derivation and validation of a short-form oral health impact profile. Community Dent Oral Epidemiol 1997;25:284–90.
36. Steele JG, Sanders AE, Slade GD, Allen PF, Lahti S, Nuttall N et al. How do age and tooth loss affect oral health impacts and quality of life? A study comparing two national samples. Community Dent Oral Epidemiol 2004;32:107–14.
37. Slade GD, Nuttall N, Sanders A, Steele J, Allen F, Lahti S. Impacts of oral disorders in Australia and the United Kingdom. Br Dent J 2005;198:489–93.
38. Carter KD, Stewart JF. National Dental Telephone Interview Survey 2002. AIHW Cat. No. DEN 128. Adelaide: AIHW Dental Statistics and Research Unit; 2003. p. 1–11.
39. Atchison KA, Davidson PL, Nakazono TT. Predisposing, enabling, and need for dental treatment characteristics of ICS-II USA ethnically diverse groups. Adv Dent Res 1997;11:223–34.
40. Gift HC, Atchison KA, Drury TF. Perceptions of the natural dentition in the context of multiple variables. J Dent Res 1998;77:1529–38.
41. Palmqvist S, Soderfeldt B, Arnbjerg D. Self-assessment of dental conditions: validity of a questionnaire. Community Dent Oral Epidemiol 1991;19: 249–51.
42. Axelsson G, Helgadottir S. Comparison of oral health data from self-administered questionnaire and clinical examination. Community Dent Oral Epidemiol 1995;23:365–8.
43. Rasbash J, Steele F, Browne W, Prosser B. A user's guide to MLwiN (Version 2), Documentation Version 2.1e. London: Multilevel Models Project; 2003.
44. Goldstein H. Multilevel statistical models. London: Arnold; 2003.
45. Hox J. Multilevel analysis: techniques and applications. Mahwah, NJ: Lawrence Erlbaum Associates; 2002.
46. Snijders T, Bosker R. Multilevel analysis: an introduction to basic and advanced multilevel modeling. London: Sage Publications; 1999.
47. Locker D. Deprivation and oral health: a review. Community Dent Oral Epidemiol 2000;28:161–9.
48. Locker D, Ford J. Evaluation of an area-based measure as an indicator of inequalities in oral health. Community Dent Oral Epidemiol 1994;22:80–5.
49. Locker D, Payne B, Ford J. Area variations in health behaviours. Can J Public Health 1996;87:125–9.
50. Diez Roux AV. Estimating neighbourhood health effects: the challenges of causal inference in a complex world. Soc Sci Med 2004;58:1953–60.
51. Boyle MH, Wilms JD. Place effects for areas defined by administrative boundaries. Am J Epidemiol 1999;149:577–85.
52. Turrell G, Hewitt B, Patterson C et al. Measuring socioeconomic position in dietary research: is choice of socioeconomic indicator important? Public Health Nutr 2003;6:191–200.
53. Turrell G, Patterson C, Oldenburg B et al. The socioeconomic patterning of survey participation and non-response error in a multilevel study of food purchasing behaviour: area- and individual-level characteristics. Public Health Nutr 2003;6:181–9.
54. Pattussi MP, Marcenes W, Croucher R, Sheiham A. Social deprivation, income inequality, social cohesion, and dental caries in Brazilian school children. Soc Sci Med 2001;53:915–25.
55. Putnam RD. Making democracy work: civic traditions in modern Italy. Princeton, NJ: Princeton University Press; 1993. p. 167.
56. Kawachi I, Berkman L. Social cohesion, social capital, and health. In: Kawachi, I, Berkman, L, editors. Social epidemiology. New York: Oxford University Press; 2000. p. 174–190.
57. Lochner K, Kawachi I, Kennedy BP. Social capital: a guide to its measurement. Health & Place 1999;5:259–70.
58. Kelly S, Hertzman C, Daniels M. Searching for the biological pathways between stress and health. Annu Rev Public Health 1997;18:437–62.
59. Brunner E. Stress and the biology of inequality. BMJ 1997;314:1472–76.
60. Genco RJ, Ho AW, Kopman J et al. Models to evaluate the role of stress in periodontal disease. Ann Periodontal 1998;3:288–302.
61. Kawachi I, Kennedy BP, Glass R. Social capital and self-rated health: a contextual analysis. Am J Public Health 1999;89:1187–93.
62. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. Science 1997;277:918–24.