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Contributions of social context to inequality in dental caries: a multilevel analysis of Japanese 3-year-old children

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Abstract – *Background:* Community context as well as individual health behavior affects oral health status. However, the contribution of social context to dental caries among people in various regions remains unclear when individual health behavior is taken into account. *Objectives:* To determine the influence of community context on dmft among 3-year-old children. *Methods:* After all Japanese municipalities ($n = 2522$) had been stratified into nine regions with three caries levels, 44 municipalities were randomly selected. Community health service workers were asked to collect information on sociodemographic characteristics, oral health-related behavior, and dental condition for 3-year-old children during community dental health check-ups. Community-related variables, including socioeconomic status, social support, and social cohesion, were obtained from census data. Multilevel analysis was used to determine the effects of social context and individual behavior on dental caries. *Results:* A total of 3301 parents (79.9%) of 3-year-old children from 39 municipalities participated in our survey, and complete information was obtained from 3086 of them. Results of the analysis showed that 90.8% ($P < 0.001$) of variance in dmft occurred at the individual level and that 9.2% ($P < 0.001$) of the variance occurred at the community level. Individual-level variables explained only 6.6% of the individual level variance in dmft. Community-level variables explained 47.2% of the community level variance. *Conclusions:* There are statistically significant effects of social context on dmft in municipalities in Japan.

Key words: caries; inequality; multilevel analysis; social context; 3-year-old child

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Although caries prevalence has been declining in most industrialized countries in the last three decades (1), the disease level among people in disadvantaged communities remains high (2, 3). Reducing inequalities in oral health has become one of the main health policy issues since the late 1990s (4). In Japan, regional inequality in early childhood caries distribution has been reported (5, 6). For example, caries prevalence in 3-year-old children in Japanese prefectures varied between 50% and 71% in 1981 and between 24% and 53% in 2001.

Although individual health behavior clearly affects individual caries experience, gender, socioeconomic status, and place of residence have been shown in previous studies to be sociodemographic risk factors for inequalities in dental caries in children (3, 4, 7). On the contrary, race and ethnicity appear to be less important than socioeconomic status (4, 8). British studies have shown that caries levels are related to the degree of social deprivation in one regional area (9, 10). In Japan, a substantial proportion of the regional inequality in early childhood caries was explained

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by socioeconomic status (6). Therefore, socioeconomic status is a powerful determinant of population health (11).

It is also known that an individual's risk of illness cannot be considered in isolation from the disease risk of the population to which they belong (12). That is, risks of individuals in a community are influenced by community context. Recently, social contextual exposure and environmental exposure have been suggested to correlate with an individual's broad range of physical and mental health outcomes (13). Therefore, it is difficult to consider the influences of community context and individual health behavior on caries experience separately. Multilevel models are appropriate for analyzing such hierarchical data, and such models enable the variance occurring at individual and community levels to be estimated separately (14, 15).

The results of a few multilevel studies on dental caries have been reported (16–18). Tellez et al. estimated that 2.4% of the variation in severity measure of dental caries occurred at the community level (17). However, they targeted only African-American families living in the poorest tracts in one US city, and the subject population was therefore limited. Pattussi et al. surveyed 1302 students (14/15 years old) in two cities in Brazil (18). Antunes et al. examined contextual and individual determinants of dental caries experience in Brazil (16). They conducted a county-wide survey including 34 550 school children (12 years old), and they revealed that community context, including the status of fluoridated water supply, affected caries experience. However, their analysis did not include individual health behavior and considered only individual demographic variables. In addition, there has been no study on relationships between primary caries experience and social context. We have found regional inequality in caries prevalence in 3-year-old children in an ecological study (6).

If community contextual influences on individual health status are substantial, a geographic-targeted population approach might be needed to reduce regional inequality. To reduce oral health inequality, it is important to reveal the community contextual influences on caries and cause of regional disparity. We hypothesized that social context significantly affects caries experience in 3-year-old children. The aims of our study were to estimate the community contextual influences on dmft in 3-year-old children in various regions.

Materials and methods

This cross-sectional survey, conducted from May 2005 to February 2006, was a collaborative study with municipalities' health sectors. Ethical approval for the study was obtained from the Hokkaido University Graduate School of Dental Medicine Ethics Committee.

Study sample

Japan has nine geographical regions including 2522 municipalities. Dental health check-ups are carried out in all municipalities several times per year. For sampling of communities with various caries levels, all Japanese municipalities were stratified by regions and the tripartite of 3-year-old children's caries prevalences in 2000. Then 44 municipalities were selected and 39 municipalities agreed to participate in our survey. We selected one or more health check-up activities for each municipality according to the population size of 3-year-old children in 2000. All participants were enrolled to avoid a selection bias or ethical problems. Informed consent was obtained from the parents.

Data collection

All Japanese municipalities have conducted surveillance of oral health status in 3-year-old children every year. Dental health check-ups are conducted by dentists employed by the municipalities at the surveillance. The dentists are told to use the World Health Organization's criteria (19) for dental examination. Our survey was a collaborative study with selected municipalities. It might be ideal to calibrate the dentists using clinical patients. However, we could only notify the dentists to follow assigned criteria. The number of children examined by one examiner could not be adjusted. It was not possible to ascertain the reliability of clinical dental data. Dental health check-ups were carried out to measure the dmft index (number of decayed, missing, and filled teeth) in 3-year-old children. Information on individual demographic characteristics and health behavior was obtained by using self-administration questionnaires. The questionnaire included 14 items on health behavior such as dietary history and oral hygiene practices. The questionnaire items were selected on the basis of results of a preliminary study and were found to be reliable and valid. Pretests were conducted during the period from October 2004 to February 2005. Fifty-seven parents of 3-year-old children in nursery schools participated. The test–retest reliability (correlation coefficient) was 0.75 ($P < 0.05$). Fifty-six parents participated in validity tests, and validity was assessed using a usual 24-hour dietary recall. The correlation of our questionnaire score with usual 24-hour dietary recall was significant ($P < 0.05$). Community level information for selected municipalities was also obtained from census data.

The variables for individual characteristics (first level) are shown in Table 1. Sex, birth order, living with or without a grandparent, parent's smoking status, and occupation of the household were recorded. The occupations of households were categorized as 'blue collar' and 'white collar'. Blue collar included physically demanding work such as farming, forestry, fishery, construction, and production and white collar included professions, managers, and administrators. Parents were asked to reply 'before 18 months of age' or '18 months of age or older' to five questions: (i) age of the initiation of toothbrushing by parents, (ii) use of fluoride toothpaste, (iii) eating sweets, (iv) drinking sweet drinks, and (v) age of termination of breast-feeding. Frequency of toothbrushing was categorized as 'less than once per day' or 'once per day or more'. Frequencies of eating sweets and drinking sweet drinks were defined as 'less than 4 days/week', '4–6 days/week', and 'every day'. Daily intake of all sweet food and drinks was categorized as '1 time or less' and '2 times or more'.

Nine community-related variables (second level) were used (20, 21). Relationships of socioeconomic statuses of individuals and populations with health have been established (13). Therefore, four variables, average income, educational level, area of dwelling per person, and unemployment rate in each municipality, were used as socioeconomic variables. The five community-related variables included number of volunteer case workers (per 100 000 residents), number of community centers (per 100 000 residents), number of dental practitioners (per 10 000 residents), municipality's expenditure for public health activities per child, and number of grocery stores per resident. Social support and social cohesion are related to health (13). The number of case workers represents social support. Municipal governments endorse volunteer case workers, and they serve to improve health and welfare of aged people, pregnant women, babies, and young children. Community centers have been established to enable people to perform social activities to enhance social cohesion and neighborhood trust. The number of dentists per 10 000 residents was used to represent access to dental health care. Municipality's expenditure for public health activities per child represents health activity in a municipality. To estimate the lifestyle related to dietary habit, data on the number of grocery stores per resident were collected (Table 2).

Table 1. Distribution of individual characteristics of 3-year-old children ($n = 3086$)

Individual characteristics	n	%	Individual characteristics	n	%
Sex			Use of fluoride toothpaste		
Male	1565	51.9	Before 18 months of age	636	17.5
Female	1521	48.1	18 months of age or older	2450	82.5
Birth of the child			Termination of breast-feeding		
Firstly born	1546	43.4	Before 18 months of age	2602	75.0
Secondary born	1143	36.5	18 months of age or older	484	25.0
Born thirdly or later	397	20.0	Initiation of taking sweet foods		
Living with/without grandparents			Before 18 months of age	2077	73.8
With	834	37.7	18 months of age or older	1009	26.2
Without	2252	62.3	Initiation of taking sweet drinks		
Smoking behavior of parents			Before 18 months of age	2042	72.6
None	1286	30.7	18 months of age or older	1044	27.4
Father or mother	1392	48.9	Frequency of intake of sweet foods		
Father and mother	408	20.4	<4 days in a week	1066	28.0
Occupation of household			4–6 days in a week	1007	31.4
Blue collar	436	18.3	Every day	1013	40.5
White collar	2650	81.7	Frequency of intake of sweet drinks		
Initiation of toothbrushing by parents			<4 days in a week	1478	35.5
Before 18 months of age	2622	82.9	4–6 days in a week	702	24.0
18 months of age or older	464	17.1	Every day	906	40.5
Frequency of toothbrushing			Frequency of intake of sweet foods and drinks per day		
<Once/day	554	23.0	≤1 time/day	1238	29.0
≥Once/day or more	2532	77.0	≥2 or more/day	1848	71.0

Table 2. Descriptive characteristics of community variables ($n = 39$)

Community variables	Mean	SD
Average income (10 000 US$)	3.5	7.3
Junior college and university graduates (%)	18.2	7.7
Area of dwelling per person (m^2)	37.6	3.3
Unemployment rate	0.042	0.009
Number of volunteer case workers per 100 000 residents	213.7	59.2
Number of community centers per 100 000 residents	24.6	26.7
Number of dentists per 10 000 residents	6.8	4.0
Expenditure for public health activities per child (US$)	2.8	0.5
Number of grocery stores per resident	0.005	0.002

Data analysis

Descriptive analyzes of caries and data from the questionnaires were carried out using SPSS (version 11.0 for Windows) (22). Questionnaires with missing values were excluded from analyzes, and all analyzes were therefore based on complete data. Associations between dmft and individual characteristics were evaluated using analysis of variance (ANOVA).

In our data set, individuals (first level) were nested in communities (second level). Then multilevel analyzes were used to determine the relative size of the variance at each level (14, 15). The multilevel software MLwiN (version 2.01) (23) was used to estimate the effects of individual health behavior variables, and community contextual variables on dmft. In the first stage, a fully unconditional model was used to estimate the variance in dmft at the individual level and community level before individual and community characteristics were taken into account. In the second and third stages, variables of individual level and community level were added to the model and changes in variances were noted. We presented fixed effect coefficients for independent variables at both individual and community levels while adjusting for random intercepts between communities. Dummy variables except age were used in the individual covariates. The community-level covariates were used as continuous variables. All continuous variables were grand mean-centered. The level of significance was set at 5%. To screen for multicollinearity, all variables were checked using Pearson's correlation coefficients (continuous variables only) or Spearman's rank correlation. For any two variables exhibiting strong multicollinearity (as determined by $|r| \geq 0.7$ or $|\rho| \geq 0.7$), one was dropped from the regression model. Because the educational-level variable was strongly correlated with average income ($r = 0.8$), this variable was excluded from the models to prevent multicollinearity.

Results

A total of 3301 parents (79.9%) in 39 municipalities participated in our survey, and 3086 (93.5% of the participants) returned completely filled-in questionnaires with their children's dental health records. Distributions of individual variables and community variables are shown in Tables 1 and 2, respectively.

Nine hundred and sixty-six children (31.3% of the children examined) had caries experience and mean dmft was 1.26 ± 2.63. Table 3 shows the dmft in 3-year-old children by individual characteristics and the bivariate association between dmft and individual characteristics determined by using ANOVA. The associations between individual variables and dmft were significant except for 'sex' and 'initiation of toothbrushing by parents'.

To estimate the social contextual influences on dmft in 3-year-old children, all data sets were analyzed in the sequence of multilevel models (Table 4). Model 1 (null model) in Table 4 showed statistically significant variations in dmft at both the individual level (6.42, $P < 0.001$) and the community level (0.65, $P < 0.001$). The variation between municipalities (9.2%) was much smaller than the variation at the individual level (90.8%).

After adjusting for individual variables (Table 4, Model 2), community-level caries variance was still significant. Only 6.6% [100(6.42–6.00)/6.42] of the individual-level variance in dmft was explained by individual variables. The coefficient of the first-level dummy variables means the change in mean dmft compared with reference categories. For example, in Model 2, children who were born thirdly or later had significantly more mean dmft by 0.73 than did those who were born firstly ($P < 0.001$).

Table 3. Distribution of dmft in 3-year-old children by individual characteristics and the bivariate association between dmft and individual characteristics

Individual characteristics	dmft	SD	Individual characteristics	dmft	SD
Sex			Use of fluoride toothpaste		
Male	1.3	2.6	Before 18 months of age	1.1	2.4 *
Female	1.2	2.7	18 months of age or older	1.3	2.7
Birth of the child			Termination of breast-feeding		
Firstly born	1.1	2.5 ***	Before 18 months of age	1.1	2.5 ***
Secondary born	1.2	2.5	18 months of age or older	2.0	3.3
Born thirdly or later	2.0	3.3	Initiation of taking sweet foods		
Living with/without grandparents			Before 18 months of age	1.4	2.8 ***
With	1.7	3.1 ***	18 months of age or older	1.0	2.3
Without	1.1	2.4	Initiation of taking sweet drinks		
Smoking behavior of parents			Before 18 months of age	1.4	2.8 ***
None	0.9	2.2 ***	18 months of age or older	1.0	2.3
Father or mother	1.4	2.7	Frequency of intake of sweet foods		
Father and mother	1.9	3.3	<4 days in a week	1.0	2.3 ***
Occupation of household			4–6 days in a week	1.2	2.5
Blue collar	1.6	3.0 ***	Every day	1.5	3.1
White collar	1.2	2.6	Frequency of intake of sweet drinks		
Initiation of toothbrushing by parents			<(4 days in a week	0.9	2.2 ***
Before 18 months of age	1.2	2.6	4–6 days in a week	1.3	2.6
18 months of age or older	1.4	2.8	Every day	1.7	3.2
Frequency of toothbrushing			Frequency of intake of sweet foods and drinks per day		
<Once/day	1.6	2.9 ***	≤1 time/day	0.9	2.2 ***
≥Once/day or more	1.2	2.5	≥2 or more/day	1.5	2.8

*$P < 0.05$, ** $P < 0.01$, ***$P < 0.001$, P-value is from ANOVA.

When the community variables were included in Model 3 (Table 4), the reduction in unexplained variations of dmft between communities was estimated. It was found that 47.2% of community-level variance in dmft [100(0.36–0.19)/0.36] was explained by community variables. The variations in dmft at the individual and community levels were 6.00 and 0.19, respectively, the difference still being statistically significant after adjusting for individual and community variables ($P < 0.001$). Some individual variables, including living without grandparents and parents with smoking habit, had a significant association with dmft. Model 3 also showed associations between community-level variables and dmft. Higher average income ($\beta = -0.36$, $P < 0.01$) and larger number of community centers per 100 000 residents ($\beta = -0.01$, $P < 0.01$) were associated with decrease in dmft. Higher municipality's expenditure for public health activities per child ($\beta = 0.44$, $P < 0.01$) and larger number of grocery stores per resident ($\beta = 135.66$, $P < 0.05$) were associated with increase in dmft.

Discussion

In this study, we simultaneously estimated variance in the dmft of 3-year-old children at individual and community levels by using multilevel analysis. A null model (Table 4, Model 1) indicated that 90.8% of the variance in dmft occurred at the individual level and that 9.2% occurred at the community level. After adjustment for individual and community characteristics, community-level variance still remained statistically significant (Table 4, Model 3). This result suggests that community context affects caries prevalence. Therefore, there might be advantages to focus on public health policies not only for individuals but also for relatively high caries level areas. A whole population approach and a targeted population approach have been effective strategies for overcoming caries inequality (24–27). Our results support such approaches based on social contextual aspects. Water fluoridation as a whole population or targeted population approach has been shown to reduce inequalities in dental decay (9, 10, 28–30). A school-based sealant program (31) and a school-based fluoride mouth rinsing program as a geographic-targeted population approach could reduce inequalities. In Japan, fluoride mouth rinsing programs have been conducted in less than 10% of schools.

Generally, the variation between communities becomes smaller with increase in community size (32). The average population size in the study by

Table 4. Association of dmft with individual-level and community-level variables determined by using multilevel regression

	Model 1		Model 2		Model 3	
Fixed effects	β	(SE)	β	(SE)	β	(SE)
Individual variables[a]						
Age			1.38	(0.29) ***	1.07	(0.29) ***
Sex (female)			0.00	(0.09)	0.00	(0.09)
Birth of the child (secondary born)			0.13	(0.10)	0.12	(0.10)
Birth of the child (thirdly or later)			0.73	(0.14) ***	0.69	(0.14) ***
Living without grandparents			−0.42	(0.11) ***	−0.37	(0.11) ***
Father or mother smokes			0.36	(0.10) ***	0.34	(0.10) ***
Father and mother smoke			0.78	(0.15) ***	0.76	(0.15) ***
Occupation (Blue collar)			0.18	(0.13)	0.15	(0.13)
Initiation of toothbrushing by parents (18 months of age or older)			0.07	(0.13)	0.08	(0.13)
Frequency of toothbrushing (<once/day)			0.14	(0.12)	0.15	(0.12)
Use of fluoride toothpaste (18 months of age or older)			0.20	(0.12) *	0.20	(0.12) *
Termination of breast-feeding (18 months of age or older)			0.90	(0.12) ***	0.89	(0.12) ***
Initiation of taking sweet foods (18 months of age or older)			−0.11	(0.13)	−0.10	(0.12)
Initiation of taking sweet drinks (18 months of age or older)			−0.13	(0.12)	−0.14	(0.12)
Frequency of intake of sweet foods (4–6 days in a week)			0.01	(0.11)	0.00	(0.11)
Frequency of intake of sweet foods (everyday)			0.17	(0.12)	0.18	(0.12)
Frequency of intake of sweet drinks (4–6 days in a week)			0.30	(0.12) **	0.29	(0.12) **
Frequency of intake of sweet drinks (everyday)			0.59	(0.12) ***	0.58	(0.12) ***
Frequency of intake of sweets per day (≥2 times/day)			0.23	(0.10) **	0.21	(0.10) *
Community variables						
Average income ($10 000)					−0.36	(0.15) **
Area of dwelling per person					−0.03	(0.03)
Unemployment rate					−10.06	(10.05)
Number of volunteer case workers per 100 000 residents					0.00	(0.00)
Number of community centers per 100 000 residents					−0.01	(0.00) **
Number of dentists per 10 000 residents					−0.05	(0.03)
Expenditure for public health activities per child (US$)					0.44	(0.18) **
Number of grocery stores per resident					135.66	(69.22) *
Intercept	1.49	(0.10) ***	0.56	(0.20) **	0.48	(0.19) **
Random effects						
Individual level variance	6.42	(0.17) ***	6.00	(0.16) ***	6.00	(0.16) ***
Community level variance	0.65	(0.14) ***	0.36	(0.09) ***	0.19	(0.06) ***
Deviance						
(−2 loglikelihood)	14615.8		14373.8		14346.3	

Model 2 had a better fit to the data than did Model 1, likelihood ratio test ($\chi^2(19) = 242.0$, $P < 0.001$).
Model 3 had a better fit to the data than did Model 2, likelihood ratio test (χ^2 $(8) = 27.5$, $P < 0.001$).
[a]All variables are categorical data except for age $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

Tellez et al. (17) was 2776, which is much smaller than that in our study (about 210 000 inhabitants per municipality). Therefore, it was expected that variance in dmft between communities in the present study would be relatively small. However, the variation at the community level in the present study (9.2%) was larger than that in the study by Tellez et al. (2.4%). The reason for the small variance in the study by Tellez et al. (17) might be the characteristics of the study population. Although community characteristics are confounded by the characteristics of the people, Tellez et al. targeted only African–American families in one US city (17). Our survey targeted different municipalities with a wide range of socioeconomic statuses. As there was a large variation of community characteristics in our study, it was possible to obtain more significant community contextual influences on caries in the present study.

Community-level variables explained 47.2% of social context when community-level variables were included in the model (Table 4, Model 3). The number of dentists in a community did not show any significant association with dmft. However, the average income had a relatively large influence on the community-level variance in dmft. This finding is supported by results of previous ecological studies showing only a slight association between number of dentists in a community and caries level (6, 33). On the contrary, a significant association between socioeconomic status and caries level has been found in past individual and ecological studies (4–10).

The number of community centers per 100 000 residents showed a significant association with dmft. Community centers provide opportunities to enhance cohesion of residents through social activities. Social cohesion refers to the extent of connectedness and solidarity among groups in society (13). Pattussi et al. (34) assessed the relationships between income inequality, social cohesion, and dental caries levels in 12-year-old children in Brazil. Their ecological study demonstrated a tendency for poor social cohesion, using homicide rate as an indirect indicator of social cohesion, to be inversely associated with percentage of caries-free children. Our study also showed a significant association between social cohesion and caries in primary teeth. However, the reason for the relation between social cohesion and dental caries is unclear.

Increase in the number of grocery stores per resident showed a significant association with higher dmft. Tellez et al. showed that caries severity increased with a larger number of grocery stores in low-income communities (17). This trend was also observed in Japanese municipalities. Increase in the number of grocery stores per resident might be a barrier to making healthier food choices. Higher municipality's expenditure for public health activities per child was also significantly associated with higher dmft. As our study is cross-sectional, it is possible that municipalities with poor health indices might have larger health-related budgets.

Only 6.6% of the individual-level variance in dmft was explained by individual-related variables (Table 4, Model 2). One of the possible reasons for the low level of explained variance is the lack of information on biological factors. We did not survey bacterial and salivary factors. From a life course perspective, factors such as child birth weight, gestational age and mother's smoking behavior can explain the individual-level variance (35, 36). These factors might be able to partly explain the remaining portion of the variance in dmft (17). However, it was difficult to obtain accurate data on child birth weight and gestational age by the self-administered questionnaire used in our study. We were able to check current smoking behavior. It was found the dmft was higher in children for whom the father or mother smokes or for whom both parents smoke than in children for whom parents do not smoke. In addition, there were limitations to estimate actual oral hygiene status and sugar intake from a questionnaire survey.

There are limitations in our study. First, this survey was a cross-sectional study, precluding inferences about causal relationships. Second, as mentioned previously, this study was a collaborative study with selected municipalities, and surveillance data were used. We could not correctly calibrate the dentists who participated in our survey. Third, individual information and information on community level factors affecting caries were limited. Accordingly, the explained variations of the individual and community levels were small. We used indirect indicators of social cohesion and social support. More direct variables derived from qualitative research indicating social capital, social cohesion, social support, and social network might have reduced the unexplained community-level variance (32). Fourth, our self-report questionnaire could be biased by social desirability or social approval (37). However, we could not avoid the social desirability bias by the self-administered questionnaire.

In conclusion, there are significant effects of social context on dmft in municipalities in Japan. Further research using more direct indicators of social context is required to elucidate mechanisms by which contexts affects dental caries.

References

1. Marthaler TM. Changes in dental caries 1953–2003. Caries Res 2004;38:173–81.
2. Vargas CM, Dye BA, Hayes KL. Oral health status of rural adults in the United States. J Am Dent Assoc 2002;133:1672–81.
3. Pitts NB, Chestnutt IG, Evans D, White D, Chadwick B, Steele JG. The dentinal caries experience of children in the United Kingdom, 2003. Br Dent J 2006;200:313–20.
4. Watt R, Sheiham A. Inequalities in oral health: a review of the evidence and recommendations for action. Br Dent J 1999;187:6–12.
5. Katayama T, Ujiie T, Osada K, Okada S. Time series analysis of annual statistics of dental health checkup for 3-year-olds. Koku Eisei Gakkai Zasshi 1986;36:609–14.
6. Aida J, Ando Y, Aoyama H, Tango T, Morita M. An ecological study on the association of public dental health activities and socio-demographic characteristics with caries prevalence in Japanese 3-year-old children. Caries Res 2006;40:466–72.
7. Reisine ST, Psoter W. Socioeconomic status and selected behavioral determinants as risk factors for dental caries. J Dent Educ 2001;65:1009–16.
8. Plamping D, Bewley BR, Gelbier S. Dental health and ethnicity. Br Dent J 1985;158:261–3.
9. Jones C, Taylor G, Woods K, Whittle G, Evans D, Young P. Jarman underprivileged area scores, tooth

decay and the effect of water fluoridation. Community Dent Health 1997;14:156–60.
10. Jones CM, Worthington H. The relationship between water fluoridation and socioeconomic deprivation on tooth decay in 5-year-old children. Br Dent J 1999;186:397–400.
11. Marmot M, Wilkinson RG, editors. Social determinants of health. New York: Oxford University Press; 1999.
12. Rose G. The strategy of preventive medicine. New York: Oxford University Press; 1992 p. 63.
13. Berkman LF, Kawachi I, editors Social epidemiology. New York: Oxford University Press; 2000.
14. Leyland AH, Goldstein H, editors. Multilevel modelling of health statistics. New York: Wiley; 2001. p.1–12.
15. Hox JJ. Multilevel analysis, techniques and applications. Mahwah: Lawrence Erlbaum Associates; 2002. p. 1–36.
16. Antunes JL, Peres MA, de Campos Mello TR, Waldman EA. Multilevel assessment of determinants of dental caries experience in Brazil. Community Dent Oral Epidemiol 2006;34:146–52.
17. Tellez M, Sohn W, Burt BA, Ismail AI. Assessment of the relationship between neighborhood characteristics and dental caries severity among low-income African-Americans: a multilevel approach. J Public Health Dent 2006;66:30–6.
18. Pattussi MP, Hardy R, Sheiham A. The potential impact of neighborhood empowerment on dental caries among adolescents. Community Dent Oral Epidemiol 2006;34:344–50.
19. World Health Organization. Oral health surveys: basic methods, 4th edn. Geneva: World Health Organization; 1997. p. 39–44.
20. Statistics and Information Department of Minister's Secretariat, Ministry of Health, Labour and Welfare. Vital Statistics of Japan. 2000. Tokyo: Health and Welfare Statistics Association; 2002.
21. Statistics Bureau, Ministry of Public Management, Home Affairs, Posts and Telecommunication, Japan. Social Observations of Shi, Ku, Machi, Mura. Tokyo: Statistical Information Institute for Consulting and Analysis; 2002.
22. SPSS Inc. SPSS for Windows version 11.0 manual. Chicago: SPSS; 2001.
23. Rasbash J, Steele F, Browne W, Prosser B. A user's guide to MLWIN version 2.1e. London: University of London; 2004.
24. Hausen H, Karkkainen S, Seppa L. Application of the high-risk strategy to control dental caries. Community Dent Oral Epidemiol 2000;28:26–34.
25. Batchelor P, Sheiham A. The limitations of a 'high-risk' approach for the prevention of dental caries. Community Dent Oral Epidemiol 2002;30:302–12.
26. Burt BA. Concepts of risk in dental public health. Community Dent Oral Epidemiol 2005;33:240–7.
27. Batchelor PA, Sheiham A. The distribution of burden of dental caries in schoolchildren: a critique of the high risk caries prevention strategy for populations. BMC Oral Health 2006;6:3.
28. Slade GD, Spencer AJ, Davies MJ, Stewart JF. Influence of exposure to fluoridated water on socioeconomic inequalities in children's caries experience. Community Dent Oral Epidemiol 1996;24:89–100.
29. Riley JC, Lennon MA, Ellwood RP. The effect of water fluoridation and social inequalities on dental caries in 5-year-old children. Int J Epidemiol 1999;28:300–5.
30. Burt BA. Fluoridation and social equity. J Public Health Dent 2002;62:195–200.
31. Kim S, Lehman AM, Siegal MD, Lemeshow S. Statistical model for assessing the impact of targeted, school-based dental sealant programs on sealant prevalence among third graders in Ohio. J Public Health Dent 2003;63:195–9.
32. O'Campo P. Invited commentary: advancing theory and methods for multilevel models of residential neighborhoods and health. Am J Epidemiol 2003;157:9–13.
33. Nadanovsky P, Sheiham A. Relative contribution of dental services to the changes in caries levels of 12-year-old children in 18 industrialized countries in the 1970s and early 1980s. Community Dent Oral Epidemiol 1995;23:331–9.
34. 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.
35. Watt RG. Emerging theories into the social determinants of health: implications for oral health promotion. Community Dent Oral Epidemiol 2002;30:241–7.
36. Peres MA, de Oliveira Latorre Mdo R, Sheiham A, Peres KG, Barros FC, Hernandez PG et al. Social and biological early life influences on severity of dental caries in children aged 6 years. Community Dent Oral Epidemiol 2005;33:53–63.
37. Hebert JR, Clemow L, Pbert L, Ockene IS, Ockene JK. Social desirability bias in dietary self-report may compromise the validity of dietary intake measures. Int J Epidemiol 1995;24:389–98.

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