Socioeconomic Inequalities in Oral Health among Middle-Aged and Elderly Japanese: NIPPON DATA2010

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ABSTRACT

Background: Most studies on socioeconomic inequalities in oral health have not considered the effects of behavioral and biological factors. In Japan, the nationwide status of inequalities remains unclear. We analyzed data from 2089 residents aged ≥40 years throughout Japan. The lowest quartile of the number of remaining teeth for each 10-year age category was defined as poor oral health. Behavioral and biological factors included smoking status, obesity, diabetes mellitus, high-sensitivity C-reactive protein, and the use of dental devices. Multiple logistic regression analyses were conducted to examine the associations of educational attainment and equivalent household expenditure (EHE) with oral health, and stratified analyses by age category were also conducted (40–64 years and ≥65 years).

Methods: We analyzed data from 2,089 residents aged ≥40 years throughout Japan. The lowest quartile of the number of remaining teeth for each 10-year age category was defined as poor oral health. Behavioral and biological factors included smoking status, obesity, diabetes mellitus, high-sensitivity C-reactive protein, and the use of dental devices. Multiple logistic regression analyses were conducted to examine the associations of educational attainment and equivalent household expenditure (EHE) with oral health, and stratified analyses by age category were also conducted (40–64 years and ≥65 years).

Results: Lower education and lower EHE were significantly associated with an increased risk of poor oral health after adjusting for age, sex, employment status, marital and living statuses, and EHE/education; the odds ratio for junior high school education compared with ≥college education was 1.84 (95% confidence interval [CI], 1.36–2.49), and the odds ratio of the lowest compared with the highest EHE quartile was 1.91 (95% CI, 1.43–2.56). Further adjustments for behavioral and biological factors attenuated but did not eliminate these associations. EHE was significantly associated with oral health among elderly adults only, with a significant interaction by age category.

Conclusions: Those with a lower education and those with lower EHE had a significantly higher risk of poor oral health, even after adjustments for behavioral and biological factors.

Key words: socioeconomic status; oral health; Japan

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INTRODUCTION

Oral health is integral and essential to quality of life and social functioning.1 Moreover, oral health has a profound effect on general health,1 as evidenced by the association between poor oral health and chronic diseases, such as cardiovascular diseases.2

A large number of epidemiological studies have reported an association between socioeconomic status (SES) and oral health in developed countries; lower socioeconomic groups are more likely than higher ones to have poor oral health.3,4 Public health research into socioeconomic inequalities in oral health has suggested causal pathways linking behavioral and biological factors to oral health.3 However, very few studies have examined the effects of these factors, particularly physiological markers, on the association between SES and oral health.6–10 Therefore, identifying the underlying causes may be useful for effective action to tackle oral health inequalities.

Previous research found that socioeconomic inequalities in general health manifested in different ways in different age categories.11 In oral health, a few studies suggested different
inequalities according to age categories; however, it is possible that these differences may depend on the measurements used. There is increasing evidence to show that socioeconomic inequalities in oral health also exist in Japan, in which most dental as well as medical care is universally covered by the public health insurance system and tax transfers. As of 2010, the co-payment rate in Japan was set at 30%, and reduced to 10% for people aged ≥70 years. Since these studies were mainly conducted in limited areas and age groups, the nationwide status of inequalities in Japan remains unclear. The nationwide study linking the Survey of Dental Diseases and Comprehensive Survey of Living Conditions in 2005 recently showed that lower equivalent household expenditure (EHE; calculated as household expenditure divided by the square root of the number of family members) was associated with an increased risk of poor oral health. However, that study did not examine the association with education. Although different SES indicators, such as education and income, reflect a central dimension of social stratification, each represents different meanings in society.

Therefore, the objective of the present study was to examine associations of education and economic status with oral health, with a focus on the effects of behavioral and biological factors and age differences, in a nationwide Japanese general population.

METHODS

Study population
In 2010, a prospective cohort study on cardiovascular diseases, the National Integrated Project for Prospective Observation of Non-communicable Disease and its Trends in the Aged 2010 (NIPPON DATA2010), was established. The study was performed with the National Health and Nutrition Survey in November 2010 (NHNS2010) and the Comprehensive Survey of Living Conditions in June 2010 (CSLC2010), which were conducted by the Ministry of Health, Labour and Welfare of Japan. The details of NHNS2010 and CSLC2010 have been described elsewhere.

In November 2010, 8,815 residents aged ≥1 year from 300 randomly selected districts throughout Japan participated in the dietary survey for NHNS2010. Among 7,229 participants aged ≥20 years, 3,873 (1,598 men and 2,275 women) had a blood test, and 2,898 (1,239 men and 1,659 women) agreed to participate in the baseline survey of NIPPON DATA2010, which also included an electrocardiographic analysis, urinalysis, and a questionnaire on cardiovascular diseases. Trained interviewers obtained informed consent before the enrollment of study participants. The Institutional Review Board of Shiga University of Medical Science (No. 22–29, 2010) approved this study.

Of 2,898 participants, 91 were excluded because it was not possible to merge the data from NHNS2010 or CSLC2010 with NIPPON DATA2010 baseline data, and 451 aged <40 years were excluded. Of the remaining 2,356 participants aged ≥40 years, 267 were excluded because of missing data on the number of remaining teeth, educational attainment, EHE, type of house, employment status, marital and living statuses, smoking status, obesity, diabetes mellitus, high-sensitivity C-reactive protein (hs-CRP), or the use of dental devices. The remaining 2,089 participants aged ≥40 years (919 men and 1,170 women) were included in the present study. The characteristics of 267 participants who were excluded from the analysis and 2,089 analytic participants were shown in eTable 1.

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Oral health
The number of remaining teeth, which was assessed for NHNS2010, was used as an indicator of oral health. Tooth loss mainly reflects a history of periodontal disease and the accumulation of caries. The number of remaining teeth was ascertainment according to responses to the question, “How many teeth do you have? Wisdom teeth, dentures, dental bridges, and dental implants are not included. Post crowns are included.” Since the number of remaining teeth decreases with advancing age, we decided to set different cut-off points of poor oral health for each age group. The lowest quartile of the number of remaining teeth for each 10-year age group was employed as the definition of poor oral health: ≤26 teeth, ≤20 teeth, ≤15 teeth, ≤8 teeth, and 0 teeth among those aged 40–49, 50–59, 60–69, 70–79, and ≥80 years, respectively (Figure 1).

Socioeconomic status (SES)
Based on the self-administered questionnaire for NIPPON DATA2010, participants were sorted into three categories of educational attainment: junior high school, high school, college or higher (college [including special training school], university, or graduate school). Monthly EHE of May 2010, the month before CSLC2010, was collected from the self-administered questionnaire for CSLC2010, and participants were grouped by quartiles of expenditure. Annual household income was also obtained from the self-administered questionnaire for NHNS2010 (<2, 2–6, or ≥6 million Japanese yen [JPY]).

Covariates
The type of house (owned or rented) was obtained using the questionnaire for CSLC2010 and was used as a covariate as EHE that included household rent, but not a mortgage. Employment status (employed [including self-employed] or unemployed) was obtained using the questionnaire for CSLC2010. Marital and living statuses were divided into married, unmarried (including never married, divorced, and widowed) and not living alone, or unmarried and living alone, using the questionnaire for NIPPON DATA2010.
Behavioral and biological factors were smoking status, obesity, diabetes mellitus, hs-CRP, and the use of dental devices. Public health nurses collected information on the smoking status, which was classified into never, former, or current. Body mass index (BMI) was calculated as body weight (kg) divided by the square of height (m²), measured with participants in light clothing without shoes for NHNS2010. Obesity was defined as BMI ≥25 kg/m², adopting the definition of the Japan Society for the Study of Obesity. Casual blood samples were obtained for NHNS2010. If a blood sample was taken after ≥8 hours of fasting, it was defined as a fasting blood sample. Participants were classified as diabetic if they met one of the following criteria: fasting plasma glucose level of ≥126 mg/dL (≥7.0 mmol/L); non-fasting plasma glucose level of ≥200 mg/dL (≥11.1 mmol/L); HbA1c ≥6.5%; and/or the use of antidiabetic medications. A hs-CRP level of >0.1 mg/dL was considered to be elevated, according to a Japanese study. The use of dental devices was ascertained from the questionnaire for NHNS2010 by asking, “Do you use any of the following devices (devices for promoting oral health): tooth brush; interdental brush; tongue brush; dental floss/floss pick.” If participants used at least one of interdental brush, tongue brush, or dental floss/floss pick, they were considered to be users.

Statistical analysis

The characteristics of participants aged 40–64 years and ≥65 years were compared using the Student’s t-test for continuous variables and the chi-squared test for categorical variables. Multiple logistic regression analyses were conducted to examine associations of education and EHE with oral health. In model 1, we calculated the odds ratio (OR) and 95% confidence interval (CI) of education or EHE adjusted for age and sex (and the type of house in the analysis of EHE only). We made further adjustments for employment status, marital and living statuses, and EHE/education (model 2), as well as behavioral and biological factors (model 3). We also stratified our models by age category (40–64 years and ≥65 years) and examined whether it modified the associations of education and EHE with oral health by including interaction terms in the models.

Sensitivity analyses were conducted using annual household income classification instead of EHE and further adjusting for the square root of the number of family members. We also conducted sex-stratified analyses and examined the interaction between sex and education/EHE.

All analyses were conducted using Stata 12.0 (StataCorp LP, College Station, TX, USA). In all analyses, a two-tailed P < 0.05 was considered to be significant.

RESULTS

Table 1 shows the characteristics of the study participants. The mean age of 2,089 participants was 63.6 (standard deviation [SD], 11.4) years, 56.0% were women, and 26.8% were educated beyond high school. Significant differences in characteristics were observed between those aged 40–64 years and those aged ≥65 years, except for sex, EHE, and obesity. The median number of remaining teeth was 23 (interquartile range, 14–27); 26 teeth (interquartile range, 20–28) among those aged 40–64 years and 19 teeth (interquartile range, 8–25) among those aged ≥65 years.

Table 2 shows the prevalence, ORs, and 95% CIs of poor oral health. Lower educational attainment and lower EHE were significantly associated with an increased risk of poor oral health after adjusting for age, sex, type of house, employment status, marital and living statuses, and EHE/education (model 2); the multivariable-adjusted OR of junior high school education compared with college education or higher was 1.84 (95% CI, 1.36–2.49), and the multivariable-adjusted OR of the lowest compared with the highest EHE quartile was 1.91 (95% CI, 1.43–2.56). After further adjustments for behavioral and biological factors, this association was somewhat attenuated but did not disappear (model 3); the corresponding ORs were 1.37 (95% CI, 1.01–1.88) and 1.75 (95% CI, 1.30–2.37), respectively. Current smoking, obesity, diabetes mellitus, elevated hs-CRP, and the non-use of dental devices were significantly associated with an increased risk of poor oral health after adjusting for age and sex. After multivariable adjustments, the associations of current smoking and diabetes mellitus with oral health remained significant.

Table 3 shows the results of stratified analyses by age categories. Educational attainment was significantly associated with oral health only among those aged 40–64 years, after adjusting for age, sex, employment status, marital and living statuses, EHE, and type of house (model 2); however, no significant interaction was found between age category and educational attainment (P = 0.51). EHE was significantly associated with oral health only among those aged ≥65 years after adjusting for age, sex, employment status, marital and living statuses, education, and type of house (model 2), with a significant interaction by the age category (P = 0.020). These

| Table 1. Characteristics of study participants: NIPPON DATA2010 |
|-----------------|-----------------|-----------------|-----------------|
| Total (N = 2,089) | 40–64 years (n = 1,052) | ≥65 years (n = 1,037) | P value* |
| Age, years, mean (SD) | 63.6 (11.4) | 54.4 (7.2) | 73.0 (5.9) | <0.001 |
| Women, n (%) | 1,170 (56.0) | 603 (57.3) | 567 (54.7) | 0.224 |
| Educational attainment, n (%) | | | | <0.001 |
| College or higher | 560 (26.8) | 395 (37.5) | 165 (15.9) | |
| High school | 593 (29.5) | 509 (48.4) | 444 (42.8) | |
| Junior high school | 576 (27.6) | 148 (14.1) | 428 (41.3) | |
| EHE, mean (SD) | 148.8 (114.6) | 151.6 (127.0) | 140.0 (100.5) | 0.265 |
| Owned a house, n (%) | 1,790 (85.7) | 882 (83.8) | 908 (87.6) | 0.015 |
| Employed, n (%) | 1,010 (48.4) | 748 (71.1) | 262 (25.3) | <0.001 |
| Marital and living statuses, n (%) | | | | <0.001 |
| Married | 1,662 (79.5) | 878 (83.5) | 784 (75.6) | |
| Single, not living alone | 202 (9.7) | 103 (9.8) | 99 (9.6) | |
| Single, living alone | 225 (10.8) | 71 (6.7) | 154 (14.8) | |
| Smoking status, n (%) | | | | <0.001 |
| Never smoker | 1,377 (65.9) | 664 (63.1) | 713 (68.8) | |
| Former smoker | 412 (19.7) | 174 (16.5) | 238 (22.9) | |
| Current smoker | 300 (14.4) | 214 (20.4) | 86 (8.3) | |
| Diabetes mellitus, n (%) | 588 (28.2) | 294 (28.0) | 294 (28.4) | 0.837 |
| EHE ≥65 years, n (%) | 249 (11.5) | 89 (8.5) | 151 (14.6) | <0.001 |
| Elevated hs-CRP (>0.1 mg/dL, n) | 449 (21.5) | 194 (18.4) | 255 (24.6) | 0.001 |
| Use of dental devices, n (%) | 769 (36.8) | 416 (39.5) | 353 (34.0) | 0.009 |
| Number of remaining teeth, median (interquartile range) | 23 (14–27) | 26 (20–28) | 19 (8–25) | |
| 0 teeth, n (%) | 159 (7.6) | 22 (2.1) | 137 (13.2) | <0.001 |
| 1–9 teeth, n (%) | 201 (9.6) | 50 (4.7) | 151 (14.6) | |
| 10–19 teeth, n (%) | 382 (18.3) | 148 (14.1) | 234 (22.6) | |
| 20–24 teeth, n (%) | 425 (20.4) | 210 (20.0) | 215 (20.7) | |
| ≥25 teeth, n (%) | 922 (44.1) | 622 (59.1) | 300 (28.9) | |

BMI, body mass index; EHE, equivalent household expenditure; hs-CRP, high-sensitivity C-reactive protein.

*Obtained using the Student’s t-test for continuous variables and the chi-squared test for categorical variables, comparing age categories.

†Thousand Japanese yen (¥/month).
associations did not materially change after further adjustments for behavioral and biological factors (model 3). The associations of behavioral and biological factors with oral health by age categories are shown in eTable 2.

Sensitivity analyses using the annual household income classification instead of EHE also revealed a significant association between household income and poor oral health; the association between household income and oral health was attenuated but did not disappear after further adjustments for behavioral and biological factors. Lower EHE was significantly associated with an increased risk of poor oral health among elderly, not middle-aged adults, with a significant interaction by age category.

In the present analysis of a nationwide survey of the general Japanese population, those with a lower education and those with lower EHE had a significantly higher risk of poor oral health. These associations were attenuated but did not disappear after further adjustments for behavioral and biological factors. Lower EHE was significantly associated with an increased risk of poor oral health among elderly, not middle-aged adults, with a significant interaction by age category.

A lower education was associated with an increased risk of poor oral health independent of EHE. Education also shapes cultural capital, which takes the form of health-related skills that foster health-promoting decisions. Education also modifies the adoption of efficacious preventive behaviors, such as oral health care and nutrient-dense food consumption.

### DISCUSSION

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#### Table 2. Associations of educational attainment and EHE with poor oral health: NIPPON DATA2010

| Educational attainment | Poor oral health/ participants (%) | Model 1 OR (95% CI) | Model 2 OR (95% CI) | Model 3 OR (95% CI) |
|------------------------|-----------------------------------|---------------------|---------------------|---------------------|
| College or higher      | 114/560 (20.4)                    | 1.00                | 1.00                | 1.00                |
| High school            | 255/953 (26.8)                    | 1.50 (1.16–1.94)    | 1.43 (1.10–1.86)    | 1.25 (0.95–1.63)    |
| Junior high school     | 197/576 (34.2)                    | 2.18 (1.62–2.92)    | 1.84 (1.36–2.49)    | 1.37 (1.01–1.88)    |
| EHE quartiles          |                                   |                     |                     |                     |
| 4th (highest)          | 98/472 (20.8)                     | 1.00                | 1.00                | 1.00                |
| 3rd                    | 137/571 (24.0)                    | 1.18 (0.88–1.59)    | 1.15 (0.85–1.55)    | 1.09 (0.80–1.48)    |
| 2nd                    | 139/521 (26.7)                    | 1.36 (1.01–1.83)    | 1.26 (0.93–1.70)    | 1.20 (0.88–1.63)    |
| 1st (lowest)           | 192/525 (36.6)                    | 2.16 (1.62–2.88)    | 1.91 (1.43–2.56)    | 1.75 (1.30–2.37)    |
| Covariates             |                                   |                     |                     |                     |
| Age (per 10-year increase) |                     | 1.06 (0.97–1.15)    | 0.95 (0.86–1.06)    | 0.98 (0.87–1.09)    |
| Sex                    |                                   |                     |                     |                     |
| Men                    | 277/919 (30.1)                    | 1.00                | 1.00                | 1.00                |
| Women                  | 289/1170 (24.7)                   | 0.76 (0.63–0.93)    | 0.72 (0.58–0.88)    | 1.13 (0.86–1.49)    |
| Type of house          |                                   |                     |                     |                     |
| Owned a house          | 470/1790 (26.3)                   | 1.00                | 1.00                | 1.00                |
| Rented a house         | 96/299 (32.1)                     | 1.36 (1.04–1.77)    | 1.21 (0.92–1.61)    | 1.26 (0.94–1.68)    |
| Employment status      |                                   |                     |                     |                     |
| Employed               | 269/1010 (26.6)                   | 1.00                | 1.00                | 1.00                |
| Unemployed             | 297/1079 (27.5)                   | 1.05 (0.83–1.32)    | 1.06 (0.84–1.34)    | 1.09 (0.86–1.38)    |
| Marital and living statuses |                     |                     |                     |                     |
| Married                | 428/1662 (25.8)                   | 1.00                | 1.00                | 1.00                |
| Single, not living alone | 64/202 (31.7)                     | 1.41 (1.03–1.95)    | 1.32 (0.95–1.83)    | 1.16 (0.83–1.62)    |
| Single, living alone   | 74/225 (32.9)                     | 1.44 (1.06–1.96)    | 1.27 (0.92–1.75)    | 1.11 (0.80–1.56)    |
| Smoking status         |                                   |                     |                     |                     |
| Never smoker           | 327/1377 (23.8)                   | 1.00                | 1.00                | 1.00                |
| Former smoker          | 121/412 (29.4)                    | 1.34 (1.00–1.80)    | 1.31 (0.96–1.78)    | 1.31 (0.96–1.78)    |
| Current smoker         | 118/300 (39.3)                    | 2.24 (1.65–3.05)    | 1.94 (1.40–2.69)    | 1.94 (1.40–2.69)    |
| Obesity (BMI ≥25.0kg/m²) |                                   |                     |                     |                     |
| No                     | 380/1501 (25.3)                   | 1.00                | 1.00                | 1.00                |
| Yes                    | 186/588 (31.6)                    | 1.32 (1.07–1.63)    | 1.15 (0.92–1.44)    | 1.15 (0.92–1.44)    |
| Diabetes mellitus      |                                   |                     |                     |                     |
| No                     | 476/1849 (25.7)                   | 1.00                | 1.00                | 1.00                |
| Yes                    | 90/240 (37.5)                     | 1.66 (1.25–2.21)    | 1.47 (1.09–1.98)    | 1.47 (1.09–1.98)    |
| Elevated hs-CRP (>0.1mg/dL) |                 |                     |                     |                     |
| No                     | 419/1640 (25.6)                   | 1.00                | 1.00                | 1.00                |
| Yes                    | 147/449 (32.7)                    | 1.37 (1.09–1.72)    | 1.15 (0.90–1.46)    | 1.15 (0.90–1.46)    |
| Use of dental devices  |                                   |                     |                     |                     |
| No                     | 456/1320 (34.6)                   | 1.00                | 1.00                | 1.00                |
| Yes                    | 119/769 (14.3)                    | 0.32 (0.26–0.41)    | 0.36 (0.28–0.46)    | 0.36 (0.28–0.46)    |

BMI, body mass index; CI, confidence interval; EHE, equivalent household expenditure; hs-CRP, high-sensitivity C-reactive protein; OR, odds ratio.

Model 1: adjusted for age (per 10-year increase), sex, and type of house (own or rent: in the analysis of EHE only).

Model 2: Model 1 + adjusted for employment status, marital and living statuses, and EHE quartiles/educational attainment.

Model 3: Model 2 + adjusted for smoking status, obesity, diabetes mellitus, elevated hs-CRP, and the use of dental devices.
reported an association between social networks and oral health, inequalities in oral health was significantly lower risk of poor oral health, whereas the potential role of social networks in health inequalities may partially explain educational inequalities in oral health, which combine individual resources with those of others, may also partially explain educational inequalities in oral health. Education increases the chance to associate with other highly-educated individuals, and their social networks promote health and widen inequalities. Since several studies have reported an association between social networks and oral health, the potential role of social networks in health inequalities may also be applied to oral health. Lower EHE was significantly associated with an increased risk of poor oral health independent of educational attainment. Some Japanese studies also found income-related inequalities in oral health and EHE-related inequalities in oral health. Socioeconomic inequalities in oral health are sometimes attributed to large sections of adult dental care being excluded from public care insurance packages in many countries. It is noteworthy that economic status is a major factor affecting oral health in Japan, in which universal health insurance covers most dental care.

Higher economic status may promote the adoption of commodities for enhancing oral health. Our results showed that use of dental devices, which is one form of dental self-care, led to a significantly lower risk of poor oral health, whereas the significant association between EHE and oral health remained even after adjusting for the use of dental devices. One study in Australia showed that the magnitude of socioeconomic inequalities in oral health was significantly attenuated by dental visits but not by dental self-care. We previously identified income-related inequality in dental visits for preventive purposes (dental scaling, fluoride, or orthodontic treatments), not for curative purposes among working-age Japanese men. Dental care in Japan has traditionally been treatment-oriented, and the prevalence of preventive dental care remains relatively low. There are extensive prevention possibilities, and prevention may actually save resources, particularly in the case of oral health, suggesting that inequalities in preventive dental visits but not dental self-care partly explain economic inequalities in oral health, as demonstrated in the present study. Since the prevention of tooth loss may help maintain a high quality of life and good general health, measures need to take advantage of preventive techniques.

Current smoking, obesity, diabetes mellitus, elevated high-sensitivity C-reactive protein (>0.1 mg/dL), and the use of dental devices.

| Table 3. Associations of educational attainment and EHE with poor oral health according to age categories: NIPPON DATA2010 |
|---------------------------------------------------------------|
| **Educational attainment**                                      |
| Poor oral health/ (%)                                          |
| Model 1 OR (95% CI) Model 2 OR (95% CI) Model 3 OR (95% CI)  |
| 40–64 years (n = 1,052)                                        |
| College or higher                                              |
| High school                                                   |
| Junior high school                                            |
| ≥65 years (n = 1,037)                                          |
| College or higher                                              |
| High school                                                   |
| Junior high school                                            |
| **EHE quartiles**                                              |
| 40–64 years (n = 1,052)                                        |
| 4th (highest)                                                 |
| 3rd                                                           |
| 2nd                                                           |
| 1st (lowest)                                                  |
| ≥65 years (n = 1,037)                                          |
| 4th (highest)                                                 |
| 3rd                                                           |
| 2nd                                                           |
| 1st (lowest)                                                  |
| **CI**, confidence interval; EHE, equivalent household expenditure; OR, odds ratio. |
| Interaction between the age category and equivalent educational attainment: Model 1, P = 0.557; Model 2, P = 0.513; Model 3, P = 0.715. |
| Interaction between the age category and EHE quartiles: Model 1, P = 0.019; Model 2, P = 0.020; Model 3, P = 0.012. |
| Model 1: adjusted for age (per 10-year increase), sex, and type of house (own or rent: in the analysis of EHE only). |
| Model 2: Model 1 + adjusted for employment status, marital and living statuses, and EHE quartiles/educational attainment. |
| Model 3: Model 2 + adjusted for smoking status, obesity (body mass index ≥25.0 kg/m²), diabetes mellitus, elevated high-sensitivity C-reactive protein (>0.1 mg/dL), and the use of dental devices. |

| Poor oral health/ participants (%) Model 1 OR (95% CI) Model 2 OR (95% CI) Model 3 OR (95% CI) |
|---------------------------------------------------------------|
| 40–64 years (n = 1,052)                                        |
| College or higher                                              |
| High school                                                   |
| Junior high school                                            |
| ≥65 years (n = 1,037)                                          |
| College or higher                                              |
| High school                                                   |
| Junior high school                                            |
| 4th (highest)                                                 |
| 3rd                                                           |
| 2nd                                                           |
| 1st (lowest)                                                  |
| 4th (highest)                                                 |
| 3rd                                                           |
| 2nd                                                           |
| 1st (lowest)                                                  |
| 4th (highest)                                                 |
| 3rd                                                           |
| 2nd                                                           |
| 1st (lowest)                                                  |
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| Model 2: Model 1 + adjusted for employment status, marital and living statuses, and EHE quartiles/educational attainment. |
| Model 3: Model 2 + adjusted for smoking status, obesity (body mass index ≥25.0 kg/m²), diabetes mellitus, elevated high-sensitivity C-reactive protein (>0.1 mg/dL), and the use of dental devices. |

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health, even after multivariate adjustments. Evidence supporting the causal association between smoking and tooth loss is consistently strong, and a large number of studies have demonstrated that diabetes mellitus is associated with an increased risk of periodontitis, which is an important cause of tooth loss as well as dental caries. The present study confirmed these findings.

Lower EHE was significantly associated with oral health only among those aged ≥65 years, with a significant interaction by the age category. Previous studies found that the magnitude of income-related inequalities in the number of remaining teeth became progressively stronger with advancing age. Toth loss is a consequence of cumulative factors over the course of an individual’s lifetime. Although variations in oral health inequalities according to age categories are still unclear partly due to the small number of studies conducted, previous studies and our present results consistently suggested that the magnitude of socioeconomic inequalities in the number of remaining teeth increased with advancing age. The number of remaining teeth may be a good reflection of inequality that has emerged toward the end of life, but is not useful early in life.

Some limitations of the present study need to be discussed. Since this was a cross-sectional study, we were unable to confirm the causal direction of the associations observed. However, poor oral health in adulthood is unlikely to affect educational levels. Furthermore, since SES indicators were self-reported, these may be subject to bias due to under- or over-reporting. In addition, the measures of oral health were also self-reported, without clinical examinations. However, previous studies in Japan confirmed the validity of the self-reported number of remaining teeth among middle-aged and elderly adults in a general population. The number of remaining teeth may have been underestimated among adults who underwent dental implant therapy.

In conclusion, the present analysis of a nationwide survey of the general Japanese population demonstrates that those with a lower education and those with lower EHE had a significantly higher risk of poor oral health. These associations were attenuated but did not disappear after further adjustments for behavioral and biological factors. Lower EHE was significantly associated with an increased risk of poor oral health among elderly, not middle-aged adults, with a significant interaction by age category. Further research is needed in order to elucidate the mechanisms by which SES affects oral health. These results will contribute to orienting public health intervention initiatives that reduce socioeconomic inequalities in oral health.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data related to this article can be found at https://doi.org/10.2188/jeaJE20170247.

REFERENCES

1. Petersen PE, Bourgeois D, Ogawa H, et al. The global burden of oral diseases and risks to oral health. Bull World Health Organ. 2005;83:661–669.
2. Persson GR, Persson RE. Cardiovascular disease and periodontitis: an update on the associations and risk. J Clin Periodontol. 2008;35(Suppl 8):362–379.
3. Watt RG. From victim blaming to upstream action: tackling the social determinants of oral health inequalities. Community Dent Oral Epidemiol. 2007;35:1–11.
4. Petersen PE, Kwan S. Equity, social determinants and public health programmes—the case of oral health. Community Dent Oral Epidemiol. 2011;39:481–487.
5. Watt RG, Sheiham A. Integrating the common risk factor approach into a social determinants framework. Community Dent Oral Epidemiol. 2012;40:289–296.
6. Sanders AE, Spencer AJ, Slade GD. Evaluating the role of dental behaviour in oral health inequalities. Community Dent Oral Epidemiol. 2006;34:71–79.
7. Wamala S, Merlo J, Boström G. Inequity in access to dental care services explains current socioeconomic disparities in oral health: the Swedish National Surveys of Public Health 2004–2005. J Epidemiol Community Health. 2006;60:1027–1033.
8. Sabbah W, Tsakos G, Sheiham A, et al. The role of health-related behaviors in the socioeconomic disparities in oral health. Soc Sci Med. 2009;68:298–303.
9. Levine ME, Kim JK, Crimmins EM. The role of physiological markers of health in the association between demographic factors and periodontal disease. J Periodontol Res. 2013;48:367–372.
10. Capuro DA, Davidson M. Socioeconomic inequalities in dental health among middle-aged adults and the role of behavioral and psychosocial factors: evidence from the Spanish National Health Survey. Int J Equity Health. 2017;16:34.
11. Galobardes B, Shaw M, Lawlor DA, et al. Indicators of socioeconomic position. In: Oakes JM, Kaufman JS, eds. Methods in Social Epidemiology. San Francisco, CA: Jossey-Bass; 2006:47–85.
12. Sanders AE, Spencer AJ. Social inequality in perceived oral health among adults in Australia. Aust N Z J Public Health. 2004;28:159–166.
13. Shen J, Wildman J, Steele J. Measuring and decomposing oral health inequalities in an UK population. Community Dent Oral Epidemiol. 2013;41:481–489.
14. Guarnizo-Herreo CC, Watt RG, Fuller E, et al. Socioeconomic position and subjective oral health: findings for the adult population in England, Wales and Northern Ireland. BMC Public Health. 2014;14:827.
15. Steele J, Shen J, Tsakos G, et al. The interplay between socioeconomic inequalities and clinical oral health. J Dent Res. 2015;94:19–26.
16. Aida J, Kondo K, Kondo N, et al. Income inequality, social capital and self-rated health and dental status in older Japanese. Soc Sci Med. 2011;73:1561–1568.
17. Ueno M, Ohara S, Inoue M, et al. Association between education level and dentition status in Japanese adults: Japan public health center-based oral health study. Community Dent Oral Epidemiol. 2012;40:481–487.
18. Ando A, Ohsawa M, Yaegashi Y, et al. Factors related to tooth loss among community-dwelling middle-aged and elderly Japanese men. J Epidemiol. 2013;23:301–306.

19. Ito K, Aida J, Yamamoto T, et al; JAGES Group. Individual- and community-level social gradients of edentulousness. BMC Oral Health. 2015;15:34.

20. Murakami K, Kondo N, Ohkubo T, et al. The effect of fathers’ and mothers’ educational level on adult oral health in Japan. Community Dent Oral Epidemiol. 2016;44:283–291.

21. Ikegami N, Yoo BK, Hashimoto H, et al. Japanese universal health coverage: evolution, achievements, and challenges. Lancet. 2011;378:1106–1115.

22. Aida J, Ando Y, Yanagisawa T. Oral health inequalities through life-stages among Japanese: a study linking the Survey of Dental Diseases and Comprehensive Survey of Living Conditions. J Dent Health. 2016;66:458–464 (in Japanese, only abstract in English).

23. Murakami K, Hashimoto H, Lee JS, et al. Distinct impact of education and income on habitual exercise: a cross-sectional analysis in a rural city in Japan. Soc Sci Med. 2011;73:1683–1688.

24. Kadota A, Okuda N, Ohkubo T, et al. The National Integrated Project for Prospective Observation of Non-communicable Disease and its Trends in the Aged 2010 (NIPPPON DATA2010): objectives, design, and population characteristics. J Epidemiol. 2018;28(Suppl 3):S2–S9.

25. Ikeda N, Takimoto H, Imai S, et al. Causal assessment of smoking versus drinking on number of natural teeth in Japanese adults. J Epidemiol. 2011;21:385–390.

26. Ministry of Health, Labour and Welfare, National Health and Nutrition Survey. http://www.mhlw.go.jp/bunya/kenkou/kenkou_eiyou.chousa.html (in Japanese). Accessed 29.08.17.

27. Ministry of Health, Labour and Welfare. The Comprehensive Survey of Living Conditions. http://www.mhlw.go.jp/toukei/list/20-21.html (in Japanese). Accessed 29.08.17.

28. Aida J, Ando Y, Akhter R, et al; JAGES Group. Individual- and community-level social gradients of edentulousness. BMC Oral Health. 2015;15:34.

29. Committee of the Japan Diabetes Society on the Diagnostic Criteria of Diabetes Mellitus, Seino Y, Nanjo K, Tajima N, et al. Report of the committee on the classification and diagnostic criteria of diabetes mellitus. J Diabetes Invest. 2010;1:212–228.

30. Arima H, Kubo M, Yonemoto K, et al. High-sensitivity C-reactive protein and coronary heart disease in a general population of Japanese: the Hisayama study. Arterioscler Thromb Vasc Biol. 2008;28:1385–1391.

31. Nicolau B, Thomson WM, Steele JG, et al. Life-course education and income on adult oral health in Japan. J Epidemiol. 2018;28(Suppl 3):S2–S9.

32. Bourdieu P. Distinction: A Social Critique of the Judgement of Taste. London: Routledge; 1984.

33. Abel T. Cultural capital and social inequality in health. J Epidemiol Community Health. 2008;62:e13.

34. Patrick DL, Lee RS, Nucci M, et al. Reducing oral health disparities: a focus on social and cultural determinants. BMC Oral Health. 2006;6(Suppl 1):S4.

35. Lareau A, Weininger EB. Cultural capital in educational research: evidence, and implications for oral health. Community Dent Oral Epidemiol. 2015;43:97–105.

36. Murakami K, Aida J, Ohkubo T, et al. Income-related inequalities in preventive and curative dental care use among working-age Japanese adults in urban areas: a cross-sectional study. BMC Oral Health. 2014;14:117.

37. Watanabe S, Nomura K, Imai S, et al. Association between diet and obesity among community-dwelling middle-aged and elderly Japanese men. J Epidemiol. 2013;23:228–232.

38. Bourdieu P. Distinction: A Social Critique of the Judgement of Taste. London: Routledge; 1984.

39. Fukuoka K, Ishikawa H, Tsuchiya J, et al. The role of hardness of contact in tooth extraction in Japan. J Epidemiol. 2006;16:214–219.

40. Murakami K, Aida J, Ohkubo T, et al. Income-related inequalities in preventive and curative dental care use among working-age Japanese adults in urban areas: a cross-sectional study. BMC Oral Health. 2014;14:117.

41. Sintonen H, Linnosmaa I. Economics of dental services. In: Culver AJ, Newhouse JP, eds. Handbook of Health Economics, volume 1B. Amsterdam: Elsevier; 2000:1251–1296.

42. Hanioka T, Ojima M, Tanaka K, et al. Causal assessment of smoking and tooth loss: a systematic review of observational studies. BMC Public Health. 2011;11:221.

43. Pampel FC, Krueger PM, Denney JT. Socioeconomic disparities in health behaviors. Annu Rev Sociol. 2010;36:349–370.

44. Rouxel PL, Heilmann A, Aida J, et al. Social capital: theory, evidence, and implications for oral health. Community Dent Oral Epidemiol. 2015;43:97–105.

45. Dietz WH, Dietz WS. Childhood obesity: the first public health problem for the 21st century. Pediatrics. 2004;113:19–20.

46. Arima H, Kubo M, Yonemoto K, et al. High-sensitivity C-reactive protein and coronary heart disease in a general population of Japanese: the Hisayama study. Arterioscler Thromb Vasc Biol. 2008;28:1385–1391.

47. Cutler DM, Lleras-Muney A. Understanding differences in health behaviors by education. J Health Econ. 2010;29:1–28.

48. Bourdieu P. Distinction: A Social Critique of the Judgement of Taste. London: Routledge; 1984.

49. Abel T. Cultural capital and social inequality in health. J Epidemiol Community Health. 2008;62:e13.

50. Patrick DL, Lee RS, Nucci M, et al. Reducing oral health disparities: a focus on social and cultural determinants. BMC Oral Health. 2006;6(Suppl 1):S4.

51. Berkman LF, Kushina A. Social network epidemiology. In: Berkman LF, Kawachi I, eds. Social Epidemiology. New York, NY: Oxford University Press; 2014:234–289.

52. Pampel FC, Krueger PM, Denney JT. Socioeconomic disparities in health behaviors. Annu Rev Sociol. 2010;36:349–370.

53. Rouxel PL, Heilmann A, Aida J, et al. Social capital: theory, evidence, and implications for oral health. Community Dent Oral Epidemiol. 2015;43:97–105.

54. Murakami K, Aida J, Ohkubo T, et al. Income-related inequalities in preventive and curative dental care use among working-age Japanese adults in urban areas: a cross-sectional study. BMC Oral Health. 2014;14:117.

55. Sintonen H, Linnosmaa I. Economics of dental services. In: Culver AJ, Newhouse JP, eds. Handbook of Health Economics, volume 1B. Amsterdam: Elsevier; 2000:1251–1296.

56. Hanioka T, Ojima M, Tanaka K, et al. Causal assessment of smoking and tooth loss: a systematic review of observational studies. BMC Public Health. 2011;11:221.

57. Pampel FC, Krueger PM, Denney JT. Socioeconomic disparities in health behaviors. Annu Rev Sociol. 2010;36:349–370.