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ORIGINAL ARTICLE

Relationship between chewing ability and 4-year mortality in a cohort of 80-year-old Japanese people

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OBJECTIVE: Poor oral health has been reported to be a risk indicator of mortality, however, few data are available regarding the relationship between chewing ability and mortality. We examined the relationship between self-assessed chewing ability and mortality in elderly subjects.

DESIGN: Prospective study.

SUBJECTS AND METHODS: Participating in the study were 697 people (277 males, 420 females) from 1282 individuals (80 years old) residing in Fukuoka Prefecture, Japan. Data on oral and systemic health status through questionnaires, accompanied by physical and laboratory blood examinations were obtained. Chewing ability was assessed based on the number of types of food each subject reported as able to chew by questionnaire.

RESULTS: A total of 108 subjects died between 1998 and 2002. Those with the lowest number of chewable foods were associated with higher risk of mortality than those with the ability to chew all of the 15 types of food surveyed [hazard ratio (HR) = 2.38, 95% confidence interval (95% CI) = 1.07–5.29], though other parameters including current smoking, low serum albumin, and poor physical health status were more significant. Further, reduced chewing ability of soft foods increased the risk (HR = 2.65, 95% CI = 1.20–5.87).

CONCLUSION: Chewing ability was associated with mortality in a population of 80-year-old community residents, and may be a predictor for survival rate.

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Keywords: chewing ability; masticatory; dental; elderly; mortality

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Introduction

The Japanese population is aging rapidly, and it has been estimated that people over 65 years of age will account for approximately 22% of the total population by 2010. In 2000, the 'Healthy Japan 21' campaign was initiated in order to promote overall fitness, including oral health, in the 21st century, with the goal of the campaign being to extend healthy life expectancy and improve the quality of life. In 1998, the 8020 Data Bank Survey, a community-based, cross-sectional survey, was designed and conducted in Japan in order to collect baseline data regarding the systemic and dental health of 80-year-old subjects, and to promote the idea that individuals should have at least 20 original teeth by the age of 80. In our previous cross-sectional study, we provided findings indicating that dental status and chewing ability were associated with systemic health status, such as electrocardiographic abnormalities, physical fitness, blood pressure, and activity of daily living in octogenarians (Takata *et al*, 2001, 2004a,b; Matsumura *et al*, 2003).

To date, associations between oral and systemic health in elderly subjects have been documented, while chronic periodontitis has been a particular focus of attention, due to its association with various chronic diseases such as cerebrovascular disease (Wu *et al*, 2000), coronary heart disease (Beck *et al*, 1996; Jansson *et al*, 2001), pulmonary diseases (Hayes *et al*, 1998), and overall mortality (DeStefano *et al*, 1993). It has been suggested that these associations may be the result of a common factor, i.e., smoking (Hujoel *et al*, 2002).

On the other hand, it remains to be fully elucidated whether chewing ability is correlated with mortality in elderly subjects, because few community-based survey results are available regarding the relationships between oral functions, such as chewing ability, and mortality (Appollonio *et al*, 1997a; Nakanishi *et al*, 1999). Most recently, Nakanishi *et al* (2005) reported that self-assessed chewing disability may be associated with a

greater risk of mortality in community-residing people aged 65 and older. However, as that survey only included questions regarding demographics, health status, and psychosocial variables, variables commonly associated with chronic diseases were not included in their analyses.

In order to analyze the effects of additional potential confounders, in the present report, we investigated the association between chewing ability and mortality in 80-year-old community dwelling subjects using a 4-year follow-up study.

Subjects and methods

Study population

The present study began as a population-based cross-sectional study performed from 1997 to 1998, known as the 8020 Data Bank Survey, which focused on the oral and systemic health conditions of 80-year-old residents in Japan. The target population in this study consisted of subjects born in 1917 who were residents of Fukuoka Prefecture, on Kyushu Island, in southern Japan. We did not consider the effects of age on changes that might potentially confound factors related to systemic condition, e.g., blood pressure, serum cholesterol, and serum glucose. All 80-year-old individuals residing in nine districts, including three cities (Buzen, Yukuhashi, and Munakata), four towns (Katsuyama, Tikujo, Toyotsu, and Kanda), one village (Shinyoshitomi), and one ward (Tobata of Kitakyushu City), were invited to participate in the survey. Of the 1282 individuals contacted, 697 (277 males, 420 females) agreed to participate, and 672 of those completed a questionnaire regarding life style, oral and systemic health, and also underwent the physical, laboratory blood, and oral examinations. The Human Investigations Committee of Kyushu Dental College approved the survey, and all subjects gave written informed consent prior to participation.

Baseline data

The baseline survey was performed in March 1998, which included a medical examination, a standardized medical history, a standardized dental examination, and laboratory tests. Demographic variables in the risk models included gender, place of residence, family status (whether the subject lived alone or not), and marital status of the person being examined. Disease risk factors evaluated during the baseline clinical examination included serum total cholesterol, systolic and diastolic blood pressure, fasting serum glucose, serum albumin, cigarette smoking status (never, past, or current), daily alcohol consumption, body mass index, regular physical activity, self-rated general health, self-rated mental health, healthcare behavior (i.e., regular check-up by a family doctor), and physical health status. The physical health status was determined by public health nurses who classified the subjects as either independent or dependent, i.e., requiring daily assistance. The subjects took part in a face-to-face interview, and answered containing 37 questions about oral and systemic health status, use of medical (or dental) services, personal hygiene and healthcare practices (including smoking habit), and medical conditions. Information on self-assessed chewing ability was based on the following question regarding the number of types of food: 'Can you chew any of the following 15 types of food?'. The response was a simple dichotomous variable (yes/no). The number of foods that subjects reported being able to chew was used as an independent variable in our analyses. To date, questionnaires concerning food intake have proved valuable in epidemiologic surveys of masticatory function in the elderly (Leake, 1990; Slade *et al*, 1996; Miura *et al*, 1998). Here, we used the criteria as described previously (Yamamoto, 1972): 15 different types of food were divided into four groups, ranging from very hard to chew to easy to chew, namely, three foods were very hard to chew (hard rice crackers, peanuts, and yellow pickled radish), six foods were moderately hard to chew (French bread, beefsteak, octopus in vinegar, pickled shallots, dried scallops, and dried cuttlefish), three foods were slightly hard to chew (konnyaku, a tubular roll of boiled fish paste, and squid sashimi), and three foods were easy to chew (boiled rice, tuna sashimi, and grilled eel).

Follow-up survey

The present study was designed to analyze the results of follow-up examinations of all of the participants in our previous study and was performed at the end of March 2002, i.e., 4 years after the baseline investigation had been conducted. As for subjects who died, we recorded the date and cause of death according to resident registration cards and official death certificates, which were available in the registers at the Public Health Centers of each district included in the study. Deaths were classified by trained physicians according to the International Classification of Disease, 10th revision. Of the 697 subjects who took part in the baseline survey, there were no losses to follow-up, as even the 14 subjects who had moved from Fukuoka Prefecture after the initial survey were successfully traced.

Statistical analysis

The associations of demographic, physical health, oral health, clinical, biochemical, and lifestyle variables with mortality were assessed using univariate Cox proportional hazards models. The Kaplan–Meier method was used to estimate cumulative survival according to the number of chewable foods categorized into four groups, which was based upon results shown in our previous reports (Takata *et al*, 2004a,b); group A ($n = 204$): all 15 foods, group B ($n = 307$): 10–14 foods, group C ($n = 134$): 5–9 foods, and group D ($n = 40$): 0–4 foods. The log rank test was used to assess the significance of differences between survival curves. The associations of chewing ability categorized based on total number of chewable foods or the ability to chew the four types of food (from 'easy' to 'very hard'), and mortality were also analyzed using multivariate Cox analysis, with adjustment for statistically significant (and marginally significant) variables shown by univariate Cox analysis as dichotomized variables, which included gender (female

vs male), physical health status (poor *vs* good), and cigarette smoking status (never, past, and current), and continuous variables, which included body mass index, serum cholesterol, fasting serum glucose, serum albumin, and diastolic blood pressure.

All statistical analyses were performed using SPSS 11.0 for Windows (SPSS, Chicago, IL, USA). The criterion for statistical significance was set at 0.05 in all of the analyses.

Results

In the 4-year period from March 1998 to March 2002, 108 of the subjects (58 males, 50 females) died. In univariate Cox proportional hazards analyses, factors showing a statistically significant relationship with mortality were gender, smoking status, physical health status, body mass index, serum total cholesterol, and serum albumin (Table 1).

The unadjusted survival rates for number of chewable foods categorized into four groups (groups A–D, see the Subjects and methods section) were analyzed using the Kaplan–Meier method, followed by log rank tests. Among the subjects, group D had a significantly increased rate of mortality when compared with group A (log rank test, $P = 0.02$). As for males, the log rank test showed that the survival curves between groups A and D had statistical significance ($P = 0.005$), while no

Table 1 Baseline characteristics of 80-year-old subjects and those who died during 4-year follow-up

Characteristic	*Entire cohort (N = 697) (%)*	*Mortality (N = 108) (%)*
Demographic		
Female	420 (60.3)	50 (46.3)*
Region		
Subjects from cities	459 (65.9)	69 (63.9)
Family status		
Live alone	162 (23.2)	18 (16.7)
Marital status		
Currently married	341 (48.9)	57 (52.8)
Physical health status		
Good	554 (79.5)	72 (66.7)**
Oral health status		
Number of teeth	8.0 (8.9)	6.8 (8.5)
Number of missing teeth	23.9 (8.9)	25.2 (8.5)
Number of chewable foods	11.6 (3.6)[a]	11.0 (3.8)
% of self-care	508 (72.9)	75 (69.4)
% of oral hygiene	287 (41.1)	32 (29.6)
Medical examinations		
Serum total cholesterol (mg dl^{-1})[b]	205.7 (38.1)	194.5 (40.1)*
Fasting serum glucose (mg dl^{-1})[b]	121.1 (53.2)	129.6 (61.5)
Serum albumin (g dl^{-1})[b]	4.23 (0.31)	4.05 (0.37)**
Systolic blood pressure (mmHg)	150.4 (23.1)	148.1 (21.8)
Diastolic blood pressure (mmHg)	78.9 (12.3)	76.9 (11.3)
Disease risk factors		
Body mass index	22.7 (3.3)	21.9 (3.2)*
Regular physical activity		
Yes	385 (55.2)	55 (50.9)
Regular checkup by family doctor		
Yes	555 (79.6)	85 (78.7)
Regular checkup by family dentist		
Yes	452 (64.8)	69 (63.9)
Self-rated general health		
Good	285 (40.9)	41 (37.9)
Self-rated mental health		
Good	607 (87.1)	96 (88.9)
Self-report of smoking		
Current	89 (1 2.8)	30 (27.8)**
Past	166 (23.8)	32 (29.6)*
Never	439 (63.0)	46 (42.6)
Unknown	3 (0.4)	0 (0)
Self-report of daily alcohol consumption		
Never	293 (42.0)	51 (47.2)
Seldom	179 (25.7)	31 (28.7)
Sometimes	63 (9.0)	7 (6.5)
Habitual	130 (18.7)	19 (17.6)
Unknown	32 (4.6)	0 (0)

Data indicate the number of subjects (%) or mean (s.d.).
[a]Data available for 685 people.
[b]Complete data for serum total cholesterol, fasting serum glucose, and serum albumin were available for 672 people and 102, respectively.
P values are by univariate Cox proportional hazards analysis: $*P < 0.01$; $**P < 0.001$.

statistically significant differences were observed for females.

To analyze whether poor chewing ability was independently related to mortality, multivariate-adjusted mortality risks were calculated, using a multivariate model in which the statistically significant and marginally significant variables shown in Table 1 were used. Table 3 shows the results of multivariate Cox proportional hazards analyses. Group D, namely subjects who were able to chew the lowest number of chewable foods, was associated with 2.4-fold higher risk of mortality than group A, which consisted of subjects able to chew all 15 foods (Table 2). Physical health status (poor), smoking status (current), and serum albumin (continuous) were also significantly associated with mortality [hazard ratio (HR) = 2.31, 95% confidence interval (95% CI) = 1.21–4.39; HR = 2.63, 95% CI = 1.47–4.70; and HR = 0.27, 95% CI = 0.14–0.53, respectively] (Table 2).

Next, we calculated the multivariate-adjusted hazard ratios according to the differences in the four types of chewable foods, i.e., from easy to chew to very hard to chew, and found that a reduction in ability to chew easy-to-chew foods increased the risk of mortality (HR for 0–1 *vs* 3 = 2.65, $P < 0.02$) (Table 3). Further, a reduction in ability to chew slightly hard-to-chew foods also tended to be associated with the risk of mortality (HR for 0–1 *vs* 3 = 1.78, $P = 0.08$) (Table 3).

Table 3 Adjusted hazard ratios of 4-year mortality according to the differences in the four types of foods that they had difficulty in chewing using Cox proportional hazards model

Type of foods	*Adjusted hazard ratio*	*95% CI*	*P value*
Number of easy-to-chew foods			
3	1.0		
2	0.98	0.49–1.97	0.95
0–1	2.65	1.20–5.87	0.02
Number of slightly hard-to-chew foods			
3	1.0		
2	0.87	0.46–1.64	0.67
0–1	1.78	0.93–3.42	0.08
Number of moderately hard-to-chew foods			
6	1.0		
4–5	0.98	0.55–1.74	0.95
2–3	1.53	0.87–2.68	0.14
0–1	1.52	0.82–2.80	0.19
Number of very hard-to-chew foods			
3	1.0		
2	0.82	0.47–1.42	0.48
0–1	1.26	0.76–2.08	0.38

Adjusted for gender, physical health status, body mass index, cigarette smoking status, serum total cholesterol, fasting serum glucose, serum albumin, and diastolic blood pressure.

Discussion

Main findings

The results from this prospective population-based study can be summarized as follows: (1) there was a close relationship between self-assessed chewing ability and mortality in a cohort study of 80-year-old subjects; (2) among the four different types of chewable foods, a reduction in ability to chew soft foods was associated with a much higher risk of mortality; and (3) chewing ability may be an independent risk marker for mortality. Our results support those obtained in previous cross-sectional surveys showing that self-assessed masticatory disability is associated with a decline in general health (Österberg *et al*, 1996; Takata *et al*, 2004a,b). Recently, a cohort study concerning the relationship between masticatory disability and mortality in Japanese aged 65 and older assessed masticatory ability according to answers by the subjects to a few simple questions (e.g., 'Can you chew any type of food?') (Nakanishi *et al*, 2005). Those results showed that self-assessed masticatory disability was significantly associated with a greater risk of mortality (HR = 1.63, 95% CI = 1.30–2.03). Further, an association between chewing ability and mortality was found, which was similar to that shown in the present study, though in a different age group. However, it is necessary to keep in mind that there are limitations to interpretation of the results of their study, as they were based solely on questionnaires, and adjustment for variables commonly associated with chronic diseases including metabolic syndrome, such as results of laboratory blood examinations, smoking status, and medical history, were not included in the statistical analyses.

In order to maintain chewing ability, replacement of missing teeth is likely important. In the present study, subjects with no replacements for missing teeth (in other words, inadequate dentition) had approximately 1.7-fold higher risk for mortality than those with at least some replacements ($P = 0.19$) (data not shown). Further, adjusted Cox analyses showed that the mortality rate for subjects with fixed dentures used to replace missing teeth was approximately 40% lower than that of subjects with removable complete dentures ($P < 0.05$) (data not shown). Our findings suggest that maintenance

Table 2 Hazard ratios of 4-year mortality by multivariate analysis using Cox proportional hazards model

Characteristic	*Adjusted hazard ratio*	*95% CI*	*P value*
Number of chewable foods			
A: 15	1.0		
B: 10–14	1.19	0.71–1.99	0.51
C: 5–9	1.19	0.63–2.25	0.59
D: 0–4	2.38	1.07–5.29	0.03
Gender: female	0.88	0.51–1.50	0.64
Physical health status: poor	2.31	1.21–4.39	0.01
Self-report of smoking			
Never	1.0		
Past	1.50	0.83–2.71	0.18
Current	2.63	1.47–4.70	0.001
Body mass index	0.95	0.89–1.02	0.14
Serum total cholesterol	1.00	0.99–1.01	0.81
Fasting serum glucose	1.00	1.00–1.01	0.07
Serum albumin	0.27	0.14–0.53	< 0.001
Diastolic blood pressure	1.00	0.98–1.02	0.84

of chewing ability with healthy natural dentition or adequate replacement of missing dentition may be important for the general health of elderly subjects. To date, several surveys have shown that the quality of life was compromised by dental and oral disorders (Sheiham *et al*, 2001a). Thus, clinicians should be aware of oral functions in order to promote and preserve the general health of elderly subjects.

This study was a part of the 8020 Data Bank Survey in Japan, in which 80-year-old populations were investigated to gain baseline data. To date, such epidemiological surveys of community-dwelling octogenarians are rare, though a recent 10-year follow-up study of 226 subjects (80 years old) showed that poor dental health was linked to increased mortality (Hämäläinen *et al*, 2003). The report noted that each missing tooth increased mortality by 2.6% over a 10-year period, while our results showed that mortality rate increased by 2.0% for each missing tooth over a 4-year period, which were similar findings.

Whether the observed association between chewing ability and systemic health is causal remains unclear at present. It is possible that common etiological factors are responsible for the observed associations, for example socioeconomic state, smoking habit, lifestyle, health-related behavior, and genetics (Anderson *et al*, 1997; Scott *et al*, 1997; Lantz *et al*, 1998; Lee, 2000). In the present study, other significant parameters in explaining mortality risk included current smoking, low serum albumin, and poor physical health. Considering that statistical significance for chewing ability was not so high, the deterioration of chewing ability may be partly contributory to mortality risk.

Poor chewing ability may be linked to limitation of their pleasure to eat and choice of a healthy diet, and further influence nutrition. It has been reported that dental status has an effect on nutritional status, as several studies have reported that impaired dentition status is associated with poor nutritional intake (Joshipura *et al*, 1996; Appollonio *et al*, 1997b; Krall *et al*, 1998; Sheiham and Steele, 2001). In addition, a longitudinal relationship between tooth loss and detrimental changes in dietary intake was recently reported (Hung *et al*, 2003). Reduction in chewing ability can influence individual food selection, resulting in marked changes in dietary intake of some key nutrients, such as non-starch polysaccharides (fiber) (Walls, 1999). It is also suggested that dental status was related to the blood levels of key nutrients, such as plasma ascorbate and plasma retinol (Sheiham *et al*, 2001b). The combined detrimental effects caused by not consuming a variety of foods and nutrients could lead to a higher risk of developing chronic diseases.

Limitations of the study

A potential weakness of this study is biases introduced by participation. The participants were 672 subjects (52.4%) from a target population of 1282 subjects and the data may be somewhat biased, as the present elderly subjects were generally in good health, and might have been more eager and/or able to participate in this survey. Thus, our findings may indicate an association in generally healthy elderly subjects. The selection bias of losses to follow-up was relatively negligible, as all of the subjects were traced by a mortality survey, though survival bias must also be considered in that context. In the total group of subjects, there were 1.5-fold more females than males. Japanese females tend to live longer than Japanese males, as the average life span in Japan in 2003 was 78.4 years for males, and 85.3 years for females. We considered that the difference in number of subjects according to gender in the present study represents a microcosm of present-day Japanese society.

One additional limitation of the present study is that the number of mortality events was very low, which implies weaknesses in the associations observed in the present study. Nevertheless, our 4-year follow-up study revealed a significant association between chewing ability and mortality. Additional follow-up of these elderly subjects may provide additional findings of interest in the future.

In conclusion, our results showed a significant relationship between chewing ability and mortality in elderly individuals, even after extensive adjustment for potential confounding variables including gender, physical health status, smoking status, and various laboratory test results. Further, a reduction in ability to chew soft foods was found to increase the risk of mortality. Thus, the ability to chew may be considered as an independent predictor of mortality in community-dwelling elderly subjects, though the present findings did not reveal causality.

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