

Interrelationship of oral health status, swallowing function, nutritional status, and cognitive ability with activities of daily living in Japanese elderly people receiving home care services due to physical disabilities

Michiko Furuta¹, Manae Komiya-Nonaka², Sumio Akifusa³, Yoshihiro Shimazaki¹, Munehisa Adachi⁴, Toshi-nori Kinoshita⁴, Takeshi Kikutani⁵ and Yoshihisa Yamashita¹

¹Section of Preventive and Public Health Dentistry, Division of Oral Health, Growth and Development, Kyushu University Faculty of Dental Science, Fukuoka, Japan,

²Department of Endodontology and Operative Dentistry, Division of Oral Rehabilitation, Kyushu University Faculty of Dental Science Fukuoka, Japan, ³Department of Health Management, School of Oral Health Science, Kyushu Dental College Kitakyushu, Japan, ⁴Itoshima Dental Association, Itoshima, Japan, ⁵Rehabilitation Clinic for Speech and Swallowing Disorders, The Nippon Dental University Hospital Tokyo, Japan

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Abstract – Objectives: Malnutrition and cognitive impairment lead to declines in activities of daily living (ADL). Nutritional status and cognitive ability have been shown to correlate with oral health status and swallowing function. However, the complex relationship among the factors that affect decline in ADL is not understood. We examined direct and indirect relationships among oral health status, swallowing function, nutritional status, cognitive ability, and ADL in Japanese elderly people living at home and receiving home care services because of physical disabilities. **Methods:** Participants were 286 subjects aged 60 years and older (mean age, 84.5 ± 7.9 years) living at home and receiving home care services. Oral health status (the number of teeth and wearing dentures) was assessed, and swallowing function was examined using cervical auscultation. Additionally, ADL, cognitive ability, and nutritional status were assessed using the Barthel Index, the Clinical Dementia Rating Scale, and the Mini Nutritional Assessment-Short Form, respectively. Path analysis was used to test pathways from these factors to ADL. **Results:** The mean number of teeth present in the participants was 8.6 ± 9.9 (edentates, 40.6%). Dysphagia, malnutrition, and severe cognitive impairment were found in 31.1%, 14.0%, and 21.3% of the participants, respectively. Path analysis indicated that poor oral health status and cognitive impairment had a direct effect on denture wearing, and the consequent dysphagia, in addition to cognitive impairment, was positively associated with malnutrition. Malnutrition as well as dysphagia and cognitive impairment directly limited ADL. **Conclusions:** A lower number of teeth are positively related to swallowing dysfunction, whereas denture wearing

Key words: activities of daily living; cognitive ability; elderly people with physical disabilities; nutritional status; oral health status

Yoshihisa Yamashita, Section of Preventive and Public Health Dentistry, Division of Oral Health, Growth and Development, Kyushu University Faculty of Dental Science, 3-1-1 Maidashi, Higashi-ku, Fukuoka 812-8582, Japan
Tel.: +81 92 642 6353;
Fax: +81 92 642 6354
e-mail: yoshi@dent.kyushu-u.ac.jp

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contributes to recovery of swallowing function. Dysphagia, cognitive impairment, and malnutrition directly and indirectly decreased ADL in elderly people living at home and receiving home nursing care. The findings suggest that preventing tooth loss and encouraging denture wearing when teeth are lost may indirectly contribute to maintaining or improving ADL, mediated by recovery of swallowing function and nutritional status.

In almost every country, the proportion of older people is increasing relative to younger age groups (1). Especially in Japan, the population is aging rapidly because of dramatic reductions in early mortality and declines in fertility. Indeed, the population aged 65 years old and older in Japan accounts for 23% of the total population in 2011 (2), and this percentage is the highest in the world. As the number of elderly people increases, so does the number of those requiring long-term nursing care, such as those who are bedridden and suffering from dementia (3).

Since 2000, nursing services supporting the daily lives of elderly individuals who require long-term care because of physical disability have been provided through the social insurance system enacted in Long-term Care Insurance Act in Japan (4). In this system, applicants for services are classified into five grades according to the severity of their physical disability, and the amount of nursing care service provided is determined by grade (5). The number of elderly receiving long-term care based on this act was about 4 million in 2010 according to a report by Japanese Ministry of Health, Labour and Welfare (6). Another report showed that 29% of elderly Japanese requiring long-term care deteriorated as measured by the grade of care service needed, and 23% of them died within 2 years (7). For elderly people receiving nursing care, further deterioration in their ability to conduct activities of daily living (ADL) such as bathing, dressing, and walking is an important concern.

Previous studies have suggested that malnutrition and cognitive impairment can lead to deterioration in ADL (8, 9), and malnutrition has been associated with cognitive impairment in elderly people (8). Moreover, nutrition and cognitive function have also been shown to correlate with oral health status (10, 11) and swallowing function (12, 13). However, these studies focused on direct relationships between bivariate. We need to also take into account that decline in ADL is affected by complex direct and indirect interactions among multiple factors. That is, it is not enough to analyze an association incorporating multiple factors as independent variables to show comprehensively how these risk factors affect deterioration in ADL.

Furthermore, most studies about the effects of oral condition on malnutrition and decline in ADL have been limited to elderly people in nursing homes and hospitals (11–13); few studies have examined these associations in elderly people living at home. In Japan, about 3 million people received home care services, and about 1 million people received facility services, such as at a nursing home, via long-term care insurance in 2010 (5, 14). In the United States, because of social trends toward reduced nursing home use, the number of disabled elderly people needing home care support has increased (15). Considering the growing number of aged people and the inevitable subsequent increase in the number who will require long-term nursing care in most developed countries, an increase in the number of elderly people requiring home care is expected to be a major issue in modern societies worldwide. Therefore, it is useful to investigate the many factors leading to a decline in ADL among elderly people living at home.

In the present study, we examined the direct and indirect effects of oral health status, including number of teeth and denture wearing, swallowing function, nutritional status, and cognitive ability, on ADL in Japanese elderly people living at home and receiving home care services because of physical disabilities. We hypothesized the following: (i) cognitive impairment leads to eating difficulties (e.g., difficulty chewing food, difficulty swallowing food), and these difficulties impair nutritional status (16); (ii) oral health status affects eating difficulties (17); (iii) cognitive impairment affects oral health status (18), or, conversely, oral health status affects cognitive impairment (19); (iv) cognitive impairment and malnutrition lead to a decline in ADL (9) (Fig. 1). The conceptual model was proposed, based on empirical evidence.

Materials and methods

Study setting and study population

This cross-sectional study was undertaken in two mid-sized municipalities in Fukuoka prefecture (western Japan) between November 2010 and

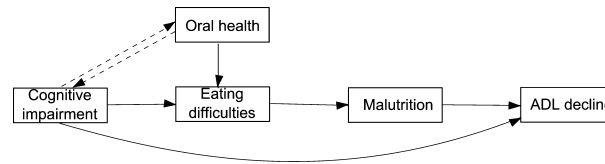


Fig. 1. The conceptual model. Dotted lines indicate paths explored the direction in this study.

February 2011. The study population comprised 337 participants aged 60 years or older who were living at home and using an in-home long-term care support center that coordinates home care services such as home nursing care, visiting rehabilitation, visiting bathing service, day service, and day care (rehabilitation) by service providers. Of these, 51 participants with missing data were excluded. Finally, 286 participants (75 men, 211 women) were included.

The study was approved by Kyushu University Institutional Review Board for Clinical Research. We obtained participants' or their family members' consent, as required for approval by the review board.

Assessment of oral health status and swallowing function

Oral health status and swallowing function were assessed by qualified dental hygienists. Oral health status was assessed by recording the number of teeth and denture wearing.

Swallowing function was examined by cervical auscultation, a non-invasive method of listening with a stethoscope to the sounds of swallowing 3 ml of water during the pharyngeal phase, following the method of Zenner et al. (20) with minor modifications. When breath sounds after swallowing material were clear, we evaluated swallowing function as normal. When stridor, coughing, or throat clearing was heard after swallowing material or when swallowing was repeated, we evaluated this as impaired swallowing function (i.e., dysphagia).

Measurement of ADL, cognitive ability, and nutritional status

Participant's ADL, cognitive ability, and nutritional status were recorded by a nurse or a care worker at the in-home long-term care support center. ADL was assessed using the Barthel Index, which covers all aspects of self-care independence in daily living activities such as transfer, walking stairs, toilet use, dressing, feeding, and bathing (21). A total score of 100 points indicates complete self-sufficiency, whereas a score of zero indicates that the person is completely dependent (21).

Cognitive ability was assessed using the Clinical Dementia Rating (CDR). CDR status was assigned according to the presence or absence of dementia and, if present, its severity (none, questionable or very mild, mild, moderate, or severe cognitive impairment), as described previously (22).

Nutritional status was evaluated using the Mini Nutritional Assessment-Short Form (MNA-SF) (23). The MNA-SF has the option of using calf circumference when body mass index is not available because of a bedridden and immobile state. Nutritional status was defined in three classifications by the MNA-SF: 0–7 points = malnourished; 8–11 points = at risk of malnutrition, and 12–14 points = well nourished.

Comorbid conditions

We assessed comorbidity with the Charlson comorbidity index (24, 25), which provides a weighted score for a participant's comorbidities taking into account how many of 19 predefined comorbid conditions an individual has, because elderly people generally live with multiple diseases, and the presence of comorbidities has a negative effect on both physical and cognitive function (26).

Statistical analysis

Bivariate associations between oral health status and swallowing function, nutritional status, cognitive ability, ADL, or confounding variables such as age, gender, and comorbid conditions were tested with the chi-square or ANOVA test. Oral health status was categorized as 20 or more teeth with dentures; 20 or more teeth without dentures; 10 to 19 teeth with dentures; 10 to 19 teeth without dentures; 0 to 9 teeth with dentures; or 0 to 9 teeth without dentures. A *P* value < 0.05 was considered to indicate statistical significance. The SPSS software (ver. 19.0 for Windows; IBM SPSS Japan, Tokyo, Japan) was used for data analyses.

To test the hypothesis, we conducted path analysis using the M-plus statistical package (27). Path analysis can be used instead of several separate regressions to examine mediating effects within a single model (28). Additionally, path analysis allows testing of causal relationships among a set

of observed variables (29). We tested the hypothesized model using path analysis (Fig. 2). The model examined the interactive effects of nine constructs. We hypothesized that cognitive ability and nutrition status directly affect ADL. We also hypothesized that the number of teeth, denture wearing, and cognitive ability precede swallowing function. Additionally, the number of teeth, denture wearing, and swallowing function precede nutrition status. Considering the association between cognitive ability and oral health status, it is possible that cognitive impairment affects oral health status (18) or, conversely, that oral health status affects cognitive impairment (19). We tested alternative path models each with different directionalities among the number of teeth, denture wearing, and cognitive ability. We adjusted for age, gender, and comorbid condition.

Data used in this study included both continuous and dichotomous variables. Thus, the path model was analyzed using weighted least-squares mean and variance adjustment estimation (WLSMV). WLSMV uses a diagonal weight matrix with robust standard errors and mean- and variance-adjusted chi-square test statistics (27). We used a significance level of $P < 0.05$ for the regression coefficients. The degree of correspondence between the hypothesized models and the actual data was assessed with a goodness-of-fit test. Criteria for the goodness-of-fit test include a comparative fit index (CFI), a Tucker-Lewis index (TLI), a root-mean-square error of approximation (RMSEA), and the weighted root-mean-square residual (WRMR). Values of >0.95 for the CFI, >0.95 for the TLI, <0.06 for the RMSEA, and

<0.90 for the WRMR are considered to indicate a good fit of the data to the model (27) (30).

Statistical power was considered for this analysis. In path analysis, sample sizes of around 150 to 200 are more desirable (31). With an alpha level of 0.05 and 286 subjects, it is estimated that the statistical power for this study reached 0.95.

Results

The participants were 75 men and 211 women. The age of the study population ranged from 61 to 104, and the mean age \pm SD was 84.5 ± 7.9 years (79.1 ± 7.9 years for men and 86.4 ± 6.9 years for women). The mean number of teeth present was 8.6 ± 9.9 , and 40.6% of participants were edentulous, while the mean number of teeth present was 14.4 ± 8.9 in 170 dentate subjects. The proportion of participants who did not visit a dental clinic was 75.9%.

Activities of daily living, cognitive ability, and nutritional status according to different categories of oral health status (including number of teeth, denture wearing), and swallowing function are presented in Tables 1 and 2. Subjects having 0 to 19 teeth and no dentures showed lower levels of ADL, cognitive function, and nutritional status than did those who had more than 20 teeth or who wore dentures. Subjects with dysphagia had lower ADL, more severe cognitive impairment, and more malnutrition than those with normal swallowing (Table 3).

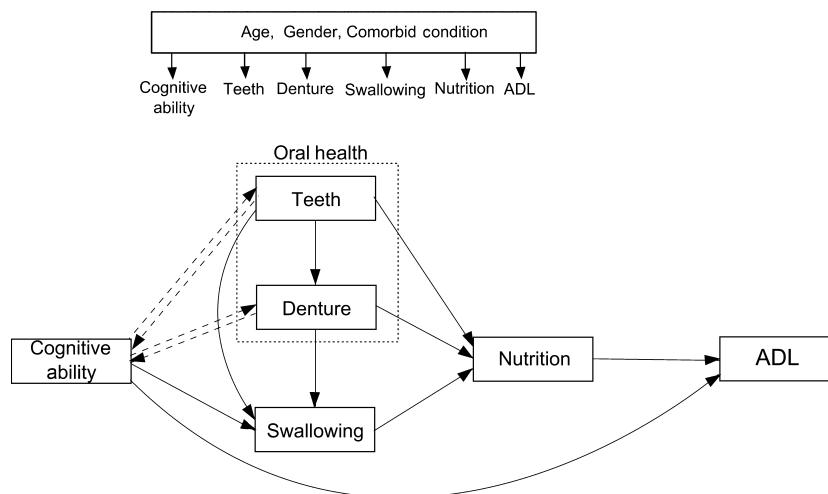


Fig. 2. The hypothesized model. The model consists of nine observed variables including confounding variables such as age, gender and comorbid conditions. Dotted lines indicate paths explored the direction in this study.

Table 1. Functional ability, cognitive function, and nutritional status according to the number of teeth [*n* (%)]

Variable	0–9 teeth (<i>n</i> = 179)	11–19 teeth (<i>n</i> = 48)	≥ 20 teeth (<i>n</i> = 59)	Total	<i>P</i> value
Age, mean ± SD	86.4 ± 7.1	82.8 ± 7.2	80.0 ± 8.5	84.5 ± 7.9	<0.001
Female	144 (80.4)	33 (68.8)	34 (57.6)	211 (71.3)	0.002
Dysphagia	57 (31.8)	16 (33.3)	16 (27.1)	89 (31.1)	0.743
Functional ability (Barthel Index), mean ± SD	57.2 ± 26.7	59.8 ± 28.4	62.1 ± 30.2	58.6 ± 27.7	0.467
Nutritional status (MNA-SF), mean ± SD	10.2 ± 2.1	9.7 ± 2.4	10.3 ± 2.6	10.1 ± 2.2	0.361
Nutrition status category					0.311
Normal (12–14)	52 (29.1)	13 (27.1)	23 (39.0)	88 (30.8)	
Risk of malnutrition (8–11)	105 (58.7)	25 (52.1)	28 (47.5)	158 (55.2)	
Malnutrition (0–7)	22 (12.3)	10 (20.8)	8 (13.6)	40 (14.0)	
Cognitive function (CDR)					0.262
None/Questionable	48 (26.8)	11 (22.9)	23 (39.0)	82 (28.6)	
Mild/Moderate	90 (50.3)	25 (52.1)	28 (47.5)	143 (50.0)	
Severe	41 (22.9)	12 (25.0)	8 (13.6)	61 (21.3)	
Comorbid condition (Charlson Comorbidity Index), mean ± SD	1.3 ± 1.1	1.5 ± 1.2	1.7 ± 1.3	1.4 ± 1.2	0.100

SD, standard deviation.

Table 2. Functional ability, cognitive function, and nutritional status according to oral health status [*n* (%)]

Variable	0–9 teeth, no denture (<i>n</i> = 26)	0–9 teeth with denture (<i>n</i> = 153)	10–19 teeth, no denture (<i>n</i> = 18)	10–19 teeth with denture (<i>n</i> = 30)	≥ 20 teeth, no denture (<i>n</i> = 49)	≥ 20 teeth with denture (<i>n</i> = 10)	<i>P</i> value
Age, mean ± SD	88.5 ± 6.6	86.1 ± 7.2	81.8 ± 7.5	83.3 ± 7.1	78.4 ± 8.2	87.6 ± 5.4	<0.001
Female	19 (73.1)	125 (81.7)	12 (66.7)	21 (70.0)	26 (53.1)	8 (80.0)	0.005
Dysphagia	15 (57.7)	42 (27.5)	7 (38.9)	9 (30.0)	13 (26.5)	2 (20.0)	0.061
Functional ability (Barthel Index), mean ± SD	38.1 ± 29.6	60.4 ± 24.8	53.9 ± 28.6	63.3 ± 28.2	59.8 ± 30.3	73.5 ± 28.0	0.001
Nutritional status (MNA-SF), mean ± SD	9.2 ± 2.1	10.4 ± 2.0	9.3 ± 2.4	10.0 ± 2.4	10.1 ± 2.8	11.4 ± 1.2	0.041
Nutritional status category							0.313
Normal (12–14)	4 (15.4)	48 (31.4)	4 (22.2)	9 (30.0)	18 (36.7)	5 (50.0)	
Risk of malnutrition (8–11)	16 (61.5)	89 (58.2)	10 (55.6)	15 (50.0)	23 (46.9)	5 (50.0)	
Malnutrition (0–7)	6 (23.1)	16 (10.5)	4 (22.2)	6 (20.0)	8 (16.3)	0 (0.0)	
Cognitive function (CDR)							0.038
None/Questionable	4 (15.4)	44 (28.8)	3 (16.7)	8 (26.7)	17 (34.7)	6 (60.0)	
Mild/Moderate	10 (38.5)	80 (52.3)	9 (50.0)	16 (53.3)	25 (51.0)	3 (30.0)	
Severe	12 (46.2)	29 (19.0)	6 (33.3)	6 (20.0)	7 (14.3)	1 (10.0)	
Comorbid condition (Charlson Comorbidity Index), mean ± SD	1.3 ± 0.9	1.3 ± 1.2	1.1 ± 0.5	1.7 ± 1.4	1.7 ± 1.4	1.6 ± 1.3	0.151

SD, standard deviation.

Path analysis

First, we estimated an initial model with all hypothesized pathways corresponding to the estimated variables directly or indirectly affecting ADL. Then, some insignificant paths were eliminated, and others who showed significant bivariate correlations were added while confirming the

model-fit indices. A final model was then estimated with only statistically significant paths retained. The final model was a fairly good fit [χ^2 (14) = 19.805; P = 0.136; CFI = 0.972; TLI = 0.945; WRWR = 0.571; RMSEA = 0.038 (0.001 to 0.074)]. Figure 3 shows parameter estimates for the final path model. The model showed the following

Table 3. Activities of daily living, cognitive ability, and nutrition status with or without dysphagia [*n* (%)]

Variable	Dysphagia (<i>n</i> = 89)	Normal (<i>n</i> = 197)	<i>P</i> value
Age, mean ± SD	84.5 ± 8.6	84.5 ± 7.5	0.991
Female	55 (61.8)	156 (79.2)	0.002
ADL (Barthel Index), mean ± SD	42.8 ± 28.3	65.8 ± 24.3	<0.001
Nutritional status (MNA-SF), mean ± SD	9.3 ± 2.3	10.5 ± 2.1	<0.001
Nutritional status category			<0.001
Normal (12–14)	16 (18.0)	72 (36.5)	
Risk of malnutrition (8–11)	52 (58.4)	106 (53.8)	
Malnutrition (0–7)	21 (23.6)	19 (9.6)	
Cognitive impairment (CDR)			<0.001
None/Questionable	32 (36.0)	60 (30.5)	
Mild/Moderate	35 (39.3)	108 (54.8)	
Severe	22 (24.7)	29 (14.7)	
Comorbid condition (Charlson Comorbidity Index), mean ± SD	1.4 ± 1.1	1.4 ± 1.2	0.976

SD, standard deviation.

significant direct paths: (i) ones from 'Age' and 'Gender' to 'Teeth'; that is, increasing age decreased the number of remaining teeth [β

(standardized coefficient) = -0.36] and females had fewer teeth than males ($\beta = -0.14$); (ii) one from 'Teeth' to 'Denture'; fewer teeth led to wearing denture ($\beta = -0.79$); (iii) one from 'Teeth' and 'Denture' to 'Swallowing'; having many teeth and wearing dentures promoted normal swallowing function ($\beta = 0.78, 0.81$, respectively); (iv) one from 'Gender' to 'Swallowing'; female tended to have normal swallowing function ($\beta = 0.22$); (v) one from 'Cognitive Ability' to 'Denture' and 'Nutrition'; a high level of cognitive ability led directly to wearing dentures and better nutritional status ($\beta = 0.23$ and 0.34 , respectively); (vi) one from 'Swallowing' to 'Nutrition'; normal swallowing function promoted normal nutritional status ($\beta = 0.25$); (vii) ones from 'Swallowing', 'Cognitive Ability', and 'Nutrition' to 'ADL'; normal swallowing function, a high level of cognitive ability, and normal nutritional status resulted in a higher level of ADL ($\beta = 0.33, 0.26$, and 0.35 , respectively); (viii) one from 'Comorbid Condition' to 'ADL'; severer comorbid condition caused a lower level of ADL ($\beta = -0.10$); and (ix) double-headed arrows among 'Age', 'Gender', 'Comorbid Condition', and 'Cognitive Ability'; age was correlated with cognitive ability, gender, and comorbid conditions. On the other hand, the number of teeth and denture wearing were not directly associated with either nutritional status or ADL.

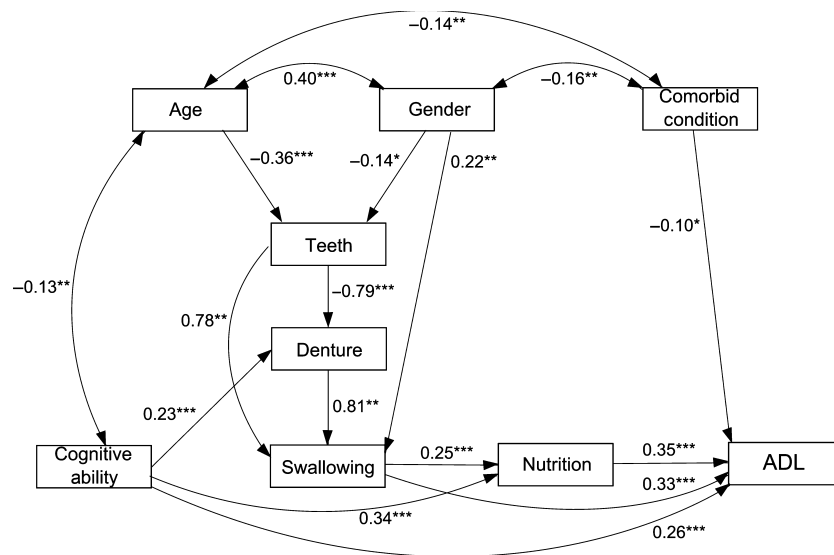


Fig. 3. The final model. Double-headed arrows indicate covariance. All significant values ($*P < 0.05$, $**P < 0.01$, $***P < 0.001$) indicate standardized coefficients. Continuous variables are 'Age', 'Comorbid Conditions' (Charlson Comorbidity Index), 'Nutrition' (MNA-SF), 'Teeth', and 'ADL' (Barthel Index). Categorical or ordered variables are 'Gender' (1 = male, 2 = female), 'Dentures' (0 = not wearing, 1 = wearing), 'Swallowing' (0 = dysphagia, 1 = normal swallowing function) and 'Cognitive Ability' (1 = severe cognitive impairment, 2 = moderate, 3 = mild, 4 = questionable, 5 = none).

Discussion

This study showed the complex pathway from cognitive ability and oral health status via swallowing function and nutritional status to ADL in aged Japanese people living at home and receiving home care, using path analysis. To the best of the authors' knowledge, this is first study to show the interaction between multiple factors leading to a decline in ADL. Path analysis is an analytical technique that allows the testing of causal models using cross-sectional data. Possible pathways leading to ADL decline, based on our findings and those of previous studies, are as follows. Having fewer teeth leads to wearing dentures, but severe cognitive impairment disrupts denture wearing because of problems in accessing dental care; chewing difficulties resulting from having fewer teeth and no dentures can lead to dysphagia; dysphagia impairs the ability of elderly people to consume adequate amounts of food to meet their nutritional needs, leading to malnutrition (16); cognitive impairment, in turn, causes potential problems related to the inability to eat or to lack of access to food (32), hence leading to malnutrition. Swallowing function, cognitive ability, and nutritional status had direct effects on ADL. This finding agrees with previous studies in elderly people (9, 13). Malnutrition and cognitive impairment are associated with poor muscle strength and reduced physical performance (33), leading to disability, which reduces the ability to perform the basic activities of daily living. Although the effect of oral health status on ADL was indirect in this study, we cannot ignore it because of the moderate association between oral health status and swallowing function. Understanding various factors related to deterioration in ADL among these subjects would contribute to considering a multilateral approach for maintaining ADL in elderly people who are living at home.

The results of the present study suggested that oral health status, as measured by indicators such as the number of teeth and denture wearing, had a direct effect on swallowing function. A previous study reported that laryngeal penetration, usually because of neuromuscular disorder, occurs with much greater frequency in edentulous elderly people who are not wearing dentures than in those who are dentulous (34). In our study, when the effect of denture wearing on swallowing function in edentulous persons was examined, 10 of 15 edentates (66.7%) without dentures showed dysphagia, whereas 29 of 101 edentates (28.7%) wearing dentures did.

Tamura et al. described that wearing dentures and keeping the appropriate mandible position and proper occlusion were important for smooth swallowing in elderly individuals (35). Additionally, loss of occlusal support and loss of mandibular stopping by occlusion may disturb the coordination of swallowing function (34).

In this study, we did not find a statistically significant association between oral health status and nutritional status in the path analysis. This finding conflicts with those of previous studies (11, 12). There may be at least two reasons that oral health status was not associated with nutritional status in the present study. First, our path model included some factors related to nutritional status, such as oral health status, swallowing function, cognitive ability, and ADL. However, previous studies (11, 12) that demonstrated an association between oral health status and nutritional status failed to incorporate these factors into their analyses. Probably, because factors other than oral health status more strongly affect nutritional status, the relationship would be less obvious in our study. Second, even when elderly people do not have enough teeth, do not wear dentures, and do not chew satisfactorily, food preparation by a caregiver may make food easy to chew and thereby prevent nutritional deterioration. Nutritional status was related to swallowing function, but not to oral health status, in this study, suggesting that swallowing function may have a greater direct effect than chewing ability on malnutrition. However, there was an association between swallowing function and oral health status in our study, and oral health status may still indirectly influence nutritional status.

Our results suggest that maintaining or improving oral health status and swallowing function indirectly or directly contribute to preventing a decline in ADL in elderly people who require home care. Yoneyama et al. (36) reported that oral care reduced febrile days and the risk of pneumonia in older patients receiving nursing care. These findings indicate that dental interventions, such as provision of dentures, treatment for dental caries or periodontal disease, professional oral care, swallowing training, and oral care training for caregivers, have a beneficial indirect effect on general health in those requiring long-term nursing care. However, our results also showed that 75.9% of participants had not received dental treatment; many elderly people requiring home care have difficulty in gaining access to professional dental care. Further efforts are needed to develop a long-term

care system or community system that provides ready access to dental services.

Our study had some limitations. Using path analysis, our study made causal inferences about the relationships among various factors related to ADL; however, the cross-sectional design means that we cannot rule out reverse causation. Further longitudinal study is needed to examine a temporal relationship. Second, we did not incorporate sociological factors, such as socioeconomic status and education level, into this study. Several studies have reported a relationship between sociological factors and oral health status, ADL, cognitive ability, and nutritional status (9, 37–39). ADLs are associated with psychosocial factors (9). Because sociological factors and psychosocial factors were considered to have more indirect effects on ADL than oral health status, cognitive ability, and nutritional status, we did not gather this information in this survey. Third, we did not assess the prevalence of specific oral diseases such as dental caries and periodontal disease. Finally, we recruited the subjects using an in-home long-term care support center in two midsized municipalities in Japan. Our sample may limit the ability to extrapolate our findings to all Japanese elderly people. Caution is warranted in generalizing our findings to the rest of the Japanese population.

In conclusion, based on the present study, we propose a potential causal pathway by which oral health status directly affects swallowing function, and dysphagia, cognitive impairment, and malnutrition directly or indirectly affect ADL in elderly people living at home and receiving home nursing care. These findings suggest that maintaining the number of teeth from a younger age and wearing dentures when teeth are lost may indirectly reduce malnutrition and subsequent ADL decline in these people.

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