used as a concept of sarcopenia in the present study. This EWGSOP consensus guide is used worldwide as diagnostic criteria of sarcopenia intended to unify views of the definition of sarcopenia.[11] However, the basic value of EWGSOP is targeted for white and black subjects in the USA and Europe. Therefore, it is difficult to apply that standard to physically different Japanese people.[19] We classified sarcopenia according to cut-off values, and basic values of SMI, grip strength and usual walking speed targeted for Asian people by the AWGS.[12] In addition, the BMI significantly decreased in the DG group. Several studies have reported that the BMI significantly decreases in subjects with sarcopenia, and as we obtained similar results in the present study, we believe that our research results are valid.[20]

A color-changeable chewing gum was used to evaluate chewing ability. With this evaluation method, the chewing ability of each participant can be evaluated easily and in a short amount of time, and it has been correlated with other chewing ability evaluation methods.[21] One previous study reported that results from color charts, like the one used in our study, correlated well with results using a color difference meter.[16] We used the same cut-off value for chewing ability as the lowest quartile used for the cut-off value for grip strength and walking speed established by the EWGSOP.[11] As a result, out of five stages of chewing ability, it was matched with the lowest quartile, by setting 1 and 2 as "poor," and the percentages as 14.1%. In a previous study with a color-changeable chewing gum, the percentages of "poor" were similar to the present results, and this supports the validity of our results.[22]

To make SSp the dependent variable, we set the cut-off value between presarcopenia and sarcopenia. This is because it is considered that not only a decline in muscle mass, but also declines in muscle strength and physical performance exist in the stage between presarcopenia and sarcopenia. It is considered to be a turning point of the decline in the QOL of older adults, as it has been reported that a decline in muscle strength of the knees and ankles are related to the balance ability of the extremities in daily life and a decline in walking speed.[23] It has also been reported that a decline in general function can be a predictive factor for the worsening of health status.[24]

We carried out a logistic regression analysis on sarcopenia-related factors, which confirmed that sarcopenia is related to age and BMI, similar to previous reports.[20] Depressed metabolism and depressed appetite could be caused by a decline in general function. It was considered that if daily nutritional intake is lacking, a negative cycle of decline in BMI, muscle mass and general function occurs.

The present study showed that there is a relationship between chewing ability and sarcopenia. Three factors of EWGSOP; muscle mass, muscle strength and physical performance, were used for the concept of sarcopenia in the present study. There have been many reports of the relationship between these three factors, and age and nutrition.[2,3] It has also been reported that both muscle strength and physical performance have a relationship with chewing ability. Moriya *et al.* reported the relationship between chewing ability and grip strength regardless of the number of existing teeth.[9] Takata *et al.* also reported the relationship between chewing ability and general function regardless of the number of existing teeth.[8] There has been no report about the relationship between general muscle mass and chewing ability, whereas there have been reports about the relationship between chewing ability related tongue thickness and brachial muscle mass.[10] Many muscles related to sarcopenia components, muscle strength and physical performance are antigravity muscles, and it was reported that a decline in the strength of antigravity muscles occurs all over the body.[25] As many muscles related to chewing ability are classified as antigravity muscles, it is considered that a decline in muscle strength occurs simultaneously.[26] It has been also reported that a decline in muscle mass causes a decline in muscle strength, and the decline in muscle strength then causes atrophy of muscles and a decline in function.[27] From these studies, it was considered that the reason for a notable relationship between chewing ability and sarcopenia in consideration of age and nutrition could be related to changes in general muscle mass and muscle mass related to chewing ability. In addition, it was seen that occlusal force and number of existing teeth have a relationship with occlusal function, but not directly with sarcopenia. Unlike a single evaluation index, such as occlusal force or number of teeth, occlusal function is a global evaluation index related with muscle of mastication, tongue, teeth and nerves. Similarly, sarcopenia is globally evaluated from muscle mass, muscle strength and general function, therefore, it could be considered that this is the background of why the relationship with sarcopenia was seen.[28]

The present research showed a relationship between chewing ability and sarcopenia, which will be meaningful to consider solutions to suppress sarcopenia in older adults in terms of dentistry in the future.

The present study had several limitations. First, the participants in this study actively attended a geriatric health examination, thus they are possibly highly conscious of their health, and can walk by themselves or attend the examination with assistance, and therefore they are a highly independent group. Therefore, these research findings might not apply to less independent groups. Second, the present study was cross-sectional, and did not prove a causal relationship between sarcopenia and chewing ability in consideration of time-course changes.

In the present study, we examined whether chewing ability is related to sarcopenia, but it could be considered that chewing-related muscle function declines as a result of sarcopenia, and leads to the aggravation of chewing ability. In addition, it could be considered that a lower amount or less quality of muscle of mastication leads to a decline in chewing ability. More details on the causal relationship need to be determined through longitudinal research and intervention research in the future.

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Disclosure statement

None of the authors has a conflict of interest to declare.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Factors associated with older adults' need for oral hygiene management by dental professionals

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Aim: The aim of the present study was to assess the need for oral hygiene management by dental professionals among older adults requiring long-term care, and to collect basic data for building a dental treatment framework on a regional level. Although healthcare providers are aware of the importance of oral care for older adults requiring long-term care, reports claim that the provision of oral care is insufficient, and a framework is being built for the provision of oral hygiene management by dental professionals.

Methods: A survey on lifestyle and oral health was carried out on 372 older adults requiring long-term care in one town in Japan. Binomial logistic regression analysis was carried out to assess factors affecting the need for oral hygiene management.

Results: A total of 66.1% of participants required oral hygiene management. The Barthel Index, Clinical Dementia Rating, oral hygiene status and other factors differed significantly with the presence or absence of oral hygiene management need. In addition to variables related to oral hygiene status (dental plaque and tongue coating), factors that significantly affected oral hygiene management need included the Clinical Dementia Rating (odds ratio 2.63, 95% confidence interval 1.08–6.41).

Conclusions: The results of the present study suggest that the need for oral hygiene management by dental professionals increases as dementia advances. However, current systems that provide regional dental care are structured based on the level of care need and the degree of independence. A dementia perspective needs to be added to these systems. **Geriatr Gerontol Int ••; ••: ••–••**

Keywords: dementia, long-term care, oral care, oral hygiene.

Introduction

According to a 2011 Survey of Dental Diseases in Japan, an estimated 38.3% of older adults have 20 natural teeth by the age of 80 years, and the ratio of older adults with a large number of natural teeth is expected to rise.[1] However, the rate of dental visits by age group peaks at age 75 years, after which it plummets. One reason for this could be the lack of a dental treatment provision framework for older adults for whom visiting dental clinics, the most common method for dental treatment in Japan, might become difficult.[2]

Meanwhile, a 1999 study found oral care to have preventive effects on fever and pneumonia in older adults requiring long-term care (LTC)[3] in Japan.[4] As a result, nurses and caregivers are becoming increasingly aware of the importance of oral care for such individuals.[5] Despite this, reports have shown that oral hygiene status remains poor in this group.[6] In addition, oral healthcare needs in older adults requiring LTC vary with the degree of functional independence. Although this topic has been examined in a number of studies, almost all of those studies are surveys on a care facility level or sample part of a group of regions.[7,8] While such studies can provide basic information for

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addressing oral healthcare needs by the degree of functional independence, their findings are insufficient to build a dental care infrastructure for older adults requiring LTC living in various different medical and care delivery environments (home, facility, hospital). Furthermore, there are numerous factors, such as age, level of care need and dementia, that affect the degree of functional independence, and it is very difficult to provide an appropriate response that takes all of these factors into account.[9–12] We therefore carried out a survey of all older adults requiring LTC living in one town as a single medical district, with the aim of clarifying the need for oral hygiene management by dental professionals, such as dentists and dental hygienists. We also assessed the factors affecting that need from basic data to build a dental care infrastructure on a regional level.

Materials and methods

We targeted 425 individuals comprising the entire population of older adults living in Yokote City (previously Omori District), Akita Prefecture, Japan, who required LTC or were certified to receive LTC based on the LTC insurance system in Japan as of 1 February 2012. Of these, 372 individuals (mean age 84.0 ± 7.6 years; 85 men, 287 women) who had undergone recent dental treatment participated, excluding 53 who did not provide consent to participate or could not participate as a result of relocation or poor health. Informed consent was obtained from each patient or their agent before participation in the survey. The present study was carried out with the approval of the ethics committee of the Tokyo Metropolitan Institute of Gerontology (Issue #.44 in 2010). The survey, carried out in February 2012, comprised a questionnaire completed by a LTC support specialist, nurse or caregiver responsible for the participant and a field measurement survey completed by four dentists. The questionnaire examined age, sex, care-needs certification, Clinical Dementia Rating (CDR),[13] Independence Degree of Daily Living for the Disabled Elderly,[14] Independence Degree of Daily Living for the Demented Elderly(Table 1),[15] the Barthel Index (BI)[16] and nutritional route. The field measurement survey covered the number of present teeth, the number of functional teeth, the state of dental plaque, the state of tongue coating and oral hygiene management needs.

In the field measurement survey, "number of present teeth" referred to the current number of remaining teeth not including non-functional tooth stumps, while the "number of functional teeth" referred to the number of present teeth plus teeth supported by dentures, bridges or implants. For assessment of oral hygiene status, an examiner visually examined teeth and dentures for the presence of plaque, and divided participants into the "present" or "absent" groups. Tongue coating status was similarly assessed by visual examination, and participants were divided into "present" or "absent" groups.

Table 1 Degree of independence of elderly dementia patients in their daily lives

Rank	Criteria for determination
I	Having a dementia, but independent in their home and in society.
II	Even if dementia symptoms and behaviors are disturbing their daily lives, someone's support enables them to be independent.
IIa	Rank II is observed outside the home.
IIb	Rank II is observed even inside the home.
III	Dementia symptoms, behaviors and communication disorders are sometimes disturbing their daily lives, such that, they need care.
IIIa	Rank III is mainly observed in the daytime.
IIIb	Rank III is mainly observed in the night-time.
IV	Dementia symptoms, behaviors and communication disorders frequently disturbing their daily lives, and they always need care.
M	There are serious psychological symptoms, problematic behaviors or severe physical diseases, such that, they need special medical treatments.

Participants were labeled as requiring oral hygiene management if the dentists carrying out the field measurement survey determined the possibility of impairment in eating or other aspects of daily life, or predicted an effect on health or other oral hygiene conditions that should not be neglected according to standards of dental medicine. Four dentists certified by the Japanese Society of Gerodontology assessed oral hygiene management need. Before starting the study, they held a case conference to discuss the number of cases and to calibrate the method for determining oral hygiene management need.

For statistical analyses, participants were divided into three groups: (i) those requiring assistance (assistance group); (ii) those requiring level 1, 2 or 3 LTC (minor care group); and (iii) those requiring level 4 or 5 LTC (major care group). CDR was divided into four groups: (i) none and suspicion (0); (ii) mild (1); (iii) moderate (2); and (iv) severe (3). Independence Degree of Daily Living for the Disabled Elderly was divided into three groups: (i) rank A (A1, A2); (ii) rank B (B1, B2); and (iii) rank C (C1, C2). No participants were rank J. Independence Degree of Daily Living for the Demented Elderly was divided into six groups: (i) none; (ii) rank I; (iii) rank II (IIa, IIb); (iv) rank III (IIIa, IIIb); (v) rank IV; and (vi)

rank M. Categories for nutritional route were: oral; tube-feeding; gastrostomy tube; intravenous; and other. For analysis, participants were divided into "oral route," for those whose response was "oral", or "non-oral route" for all others.

For significance testing, χ^2-tests were carried out on categorical variables, and unpaired *t*-tests on continuous variables. Binomial logistic regression analysis was carried out to assess factors affecting the need for oral hygiene management. Tests were carried out with oral hygiene management need (present or absent) as a dependent variable, factors that showed significant differences as independent variables, and age and sex as covariates. For sex and nominal scales represented by "absent" or "present," dummy variables of 0 for male + absent and 1 for female + present were used. Before logistic regression analysis, dependent variables for which the correlation coefficient was >0.8 were deleted in order to avoid multicollinearity. Statistical analyses were carried out with SPSS Statistics 20 (IBM, Armonk, NY, USA), with a 5% level of significance.

Results

The results for each variable related to oral hygiene management need are shown in Table 2 by group. A total of 246 participants (66.1%) were determined to have a need for oral hygiene management.

No age or sex differences were seen in oral hygiene management need. For care classification, the rate of "need present" was higher in the mild care and major care groups ($P = 0.002$). The rate of "absent" was higher in the CDR0 group, and the rate of "present" was higher

Table 2 Comparison of variables by the presence or absence of oral hygiene management need

Variable		Oral hygiene management needs		*P*-value
	Total ($n = 372$)	Unnecessary ($n = 126$)	Necessary ($n = 246$)	
Sex (female/%)	287 (77.2)	98 (34.1)	189 (65.9)	NS
Care-needs certification, *n* (%)				
Assistance group	17 (4.6)	10 (58.8)	7 (41.2)	**
Minor care group	174 (46.8)	69 (39.7)	105 (60.3)	
Major care group	181 (48.7)	47 (26.0)	134 (74.0)	
BI (mean ± SD)	33.8 ± 33.7	45.6 ± 34.9	27.8 ± 31.4	*
CDR, *n* (%)				
0: None	80 (21.5)	46 (57.5)	34 (42.5)	**
1: Mild	53 (14.2)	23 (43.4)	30 (56.6)	
2: Moderate	98 (26.3)	28 (28.6)	70 (71.4)	
3: Severe	141 (37.9)	29 (20.6)	112 (79.4)	
Independence Degree of Daily Living for the Disabled Elderly R, *n* (%)				
Rank A	124 (33.3)	58 (46.8)	66 (53.2)	**
Rank B	99 (26.6)	31 (31.3)	68 (68.7)	
Rank C	149 (40.1)	37 (24.8)	112 (75.2)	
Independence Degree of Daily Living for the Demented Elderly R, *n* (%)				
None	22 (5.9)	12 (54.5)	10 (45.5)	**
Rank I	9 (2.4)	4 (44.4)	5 (55.6)	
Rank II	111 (29.8)	52 (46.8)	59 (53.2)	
Rank III	101 (27.2)	30 (29.7)	71 (70.3)	
Rank IV	110 (29.6)	23 (20.9)	87 (79.1)	
Rank M	19 (5.1)	5 (26.3)	14 (73.7)	
Oral ingestion (yes/%)	304 (81.7)	110 (36.2)	194 (63.8)	*
No. present teeth (mean ± SD)	3.9 ± 6.9	3.2 ± 6.9	4.2 ± 6.9	NS
No. functional teeth (mean ± SD)	15.2 ± 12.5	19.3 ± 12.1	13.1 ± 12.2	NS
State of dental plaque (yes/%)	142 (38.2)	15 (10.6)	127 (89.4)	**
State of tongue coating (yes/%)	231 (62.1)	53 (22.9)	178 (77.1)	**

For significance testing, χ^2-tests were carried out on categorical variables and unpaired *t*-tests on continuous variables.
*$P < 0.05$, **$P < 0.01$. BI, Barthel Index; CDR, Clinical Dementia Rating; NS, not significant.

Table 3 Results of univariate and multiple logistic regression analysis with oral hygiene management need as the dependent variable

Variable	Univariate			Multivariate		
	OR	95% CI	*P*-value	OR	95% CI	*P*-value
Age	1.02	1.00–1.05	NS	1.02	0.98–1.06	NS
Sex (male/female)	0.95	0.57–1.58	NS	1.06	0.50–2.23	NS
Care-needs certification						
Assistance group/Minor care group 1,2,3	2.15	0.77–5.98	NS	1.41	0.35–5.75	NS
Assistance group/Major care group 4,5	3.95	1.40–11.11	**	0.95	0.18–4.90	NS
CDR						
0/1	1.74	0.86–3.52	NS	0.94	0.37–2.37	NS
0/2	3.30	1.76–6.18	**	2.53	1.03–6.18	*
0/3	5.08	2.74–9.41	**	5.22	1.86–14.64	**
Independence Degree of Daily Living for the Disabled Elderly						
A/B	1.83	1.05–3.19	*	1.63	0.62–4.23	NS
A/C	2.51	1.50–4.21	**	1.11	0.30–4.06	NS
Independence Degree of Daily Living for the Demented Elderly						
None/I	1.60	0.33–7.70	NS.	2.16	0.25–18.54	NS
None/II	1.35	0.54–3.40	NS	1.16	0.29–4.65	NS
None/III	2.80	1.09–7.20	*	0.97	0.21–4.49	NS
None/IV	4.17	1.59–10.95	**	1.19	0.24–6.07	NS
None/M	3.41	0.91–12.83	NS	0.70	0.09–5.55	NS
BI	0.99	0.98–0.99	**	0.99	0.97–1.01	NS
Oral ingestion (no/yes)	0.57	0.31–1.05	NS	0.20	0.71–5.19	NS
State of dental plaque (no/yes)	9.19	4.92–17.18	**	11.29	5.52–23.13	**
State of tongue coating (no/yes)	3.65	2.31–5.76	**	3.98	2.25–7.03	**

Forced entry analysis. *$P < 0.05$, **$P < 0.01$. BI, Barthel Index. CDR, Clinical Dementia Rating; NS, not significant.

in the CDR1 and higher group ($P < 0.001$). For Independence Degree of Daily Living for the Disabled Elderly, the rate of "present" was higher for higher levels of being bedridden ($P < 0.001$). For Independence Degree of Daily Living for the Demented Elderly, the rate of "present" was higher among rank III, IV and M (severe) individuals ($P < 0.001$). The rate of "present" was higher in the oral route group ($P = 0.046$).

For field measurements, no differences were observed for the number of present teeth or the number of functional teeth, but the rate of having a need for oral hygiene management was higher among those with plaque or tongue coating for oral hygiene status ($P < 0.001$; Table 2).

For items where significant differences were observed between the presence or absence of oral hygiene management need in univariate analysis (care need certification, CDR, Independence Degree of Daily Living for the Disabled Elderly, Independence Degree of Daily Living for the Demented Elderly, BI, nutritional route, plaque and tongue coating), we first carried out univariate logistic regression analysis adjusting for age and sex. All items showing significant differences were used as independent variables in the multivariate analysis, with oral hygiene management need used as the dependent variable (Table 3).

A significant association was observed between CDR0-CDR2, CDR0-CDR3, presence or absence of plaque and presence or absence of tongue coating. The odds ratios for "need present" compared with "need absent" were, in order: (CDR2 compared with CDR0) 2.63 (95% confidence interval [CI] 1.08–6.41, $P = 0.042$); (CDR3 compared with CDR0) 4.80 (95% CI 1.73–13.29, $P = 0.002$); (plaque present compared with plaque absent) 11.17 (95% CI 5.47–22.82, $P < 0.001$); and (tongue coating present compared with tongue coating absent) 3.75 (95% CI 2.15–6.54, $P < 0.001$).

Discussion

We carried out a survey of all older adults requiring LTC in one town as a single medical district, with the aim of clarifying the need for oral hygiene management by dental professionals, such as dentists and dental hygienists, and the factors affecting that need using basic data to build a dental care infrastructure on a

regional level. As the sample excluded 53 individuals who did not participate in the field measurement survey due to poor health or other reasons, the study was not a complete inventory. However, assuming that those individuals would have a need for oral hygiene management by a dental professional, would give an even higher ratio than the 66.1% we obtained for those with an oral hygiene management need among older adults requiring LTC. These results might also be useful as basic data to build a framework for providing oral healthcare. These findings could therefore be considered quite useful.

In the present study, the need for oral hygiene management from a dental professional was determined holistically based on examinations by dentists who carried out field measurements. Although this method is not objective, it was selected as the main assessment measure after determining that a holistic diagnosis was required, based on reports that many factors, such as the degree of functional independence, in addition to the oral hygiene status, might affect the need for oral hygiene management in older adults requiring LTC.[17]

Factors that differed significantly by univariate analysis between those who need and those who do not need oral hygiene management were variables related to care need certification, CDR, Independence Degree of Daily Living for the Disabled Elderly, Independence Degree of Daily Living for the Demented Elderly, BI, nutritional route, plaque and tongue coating. These results are largely congruent with previous findings.[8,18] Multivariate analysis showed poor oral hygiene status, such as the presence of plaque or tongue coating, to significantly affect the need for oral hygiene management. This suggests that holistic diagnosis of the oral hygiene management need by dentists who carried out field measurements is appropriate.

As aforementioned, factors that determine the need for oral hygiene management from a dental professional have been reported to be the degree of functional independence and cognition function, and the presence or absence of oral ingestion in addition to direct indicators of oral hygiene, such as plaque and tongue coating. Those reports suggest that the need for oral health management is not the only direct indicator of oral hygiene status.

Therefore, all items, including plaque and tongue coating, showing significant differences were used as independent variables in the multivariate analysis, with oral hygiene management need used as the dependent variable. The results show that the presence of plaque or tongue coating for oral hygiene status and the severity of CDR significantly affect the need for oral hygiene management.

In the present study, participants were labeled as requiring oral hygiene management based on all evaluation results if the dentists carrying out the field measurement survey determined the possibility of impairment in eating or other aspects of daily life, or predicted an effect on health or other oral hygiene conditions that should not be neglected according to standards of dental medicine. The results obtained from such a comprehensive evaluation and analyses showing that CDR, besides plaque and tongue coating, significantly affects the need of oral hygiene management, is quite interesting. In particular, as the increased number of dementia patients has gained worldwide attention, the results presented have added importance.

Furthermore, the odds ratio increased with greater severity of dementia, and severe dementia was strongly related to oral hygiene management need. This might be very important information. The oral hygiene of older adults requiring LTC has been assumed to vary with the degree of functional independence, and field surveys on oral health have been carried out separately by age or degree of functional independence.[7,19] However, many recent surveys in Japan have found that oral hygiene status is not related to the level of care need or activities of daily living.[20,21] This could be the result of large individual differences among older adults,[22] even in the same age group, a strong effect of lower limb function and other physical functions on care need classification that hinder the effects of sanitary practices, or other reasons.[23,24] Furthermore, as oral care is known to help prevent pneumonia,[4] the importance of oral care for older adults requiring LTC is widely recognized among nurses and caregivers, and such professionals might be providing adequate care as a result.[25,26]

Reasons for the strong effect of dementia severity could include a lack of cooperation in oral care by older adults requiring LTC with severe dementia, or an increased burden from aspects of nursing care other than oral care for family members and caregivers, tying up time that could otherwise be used for oral hygiene.[4] In the present study, CDR was a significant factor, but Independence Degree of Daily Living for the Demented Elderly, also a measure of dementia, was not significantly relevant. This might be a result of the nature of CDR as an indicator aimed at measuring dementia severity based on memory, orientation, judgment, problem solving skills and other such variables.[8] In contrast, the objective of the Independence Degree of Daily Living for the Demented Elderly is to assess the level of functional independence, and it is not a direct measure of dementia severity. CDR is a simple measure that can be used in oral interviews with family members or other caregivers, and should be used for assessment when providing dental care to older adults requiring LTC.

According to estimates, there will be 3.3 million individuals with dementia in Japan in 2026. Japan therefore needs to promptly build a framework for providing medical and nursing care on a regional level, to enable

older people with dementia to continue living in the community to which they have become accustomed.[27] In the present study, we determined that the need for oral hygiene management by a dental professional increases with increasing severity of dementia. This suggests the need to build a framework to provide oral healthcare that encompasses a dementia perspective. As dementia progresses, it frequently becomes difficult for family members and other caregivers to provide oral care due to refusal of such care and an increase in the overall care burden.[4,21] Furthermore, many individuals avoid visiting the dentist even when their oral cavity is dirty or they have foul breath, because visiting dental clinics is too difficult.[28] Pneumonia is the cause of death in 70% of individuals with Alzheimer's disease, who are reported to have a higher mortality rate than other older adults.[29] This means that collaboration with dental professionals is essential when building a regional framework for providing oral health-related medical and nursing care to older people with dementia in the community.

New laws on dental and oral health were established in Japan in August 2011, and an environment is being built to enable all citizens to receive appropriate dental care and oral healthcare services throughout their life. The present findings could aid in this task.

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Disclosure statement

No potential conflicts of interest were disclosed.

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ORIGINAL ARTICLE: SOCIAL RESEARCH, PLANNING AND PRACTICE

Relationship between swallowing function and the skeletal muscle mass of older adults requiring long-term care

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Aim: The present study investigated the risk factors for dysphagia among older adults who require long-term care, and also examined their systemic decrease in skeletal muscle mass.

Methods: We evaluated 399 people who required long-term care and who were residing in Omori town, Yokote city, Akita prefecture, Japan. We then analyzed data from 255 participants who had complete information available regarding their sex, age, case history (stroke, Parkinson's disease and dementia), Barthel Index, Skeletal Muscle Mass Index, oral function test and modified water swallowing test results. Participants' water swallowing test results were used to create groups with good or poor swallowing function, and a univariate analysis was carried out for each parameter. Parameters with a *P*-value of <0.25 in the univariate analysis were subsequently included in a multiple logistic regression model as explanatory variables, and good or poor swallowing function were defined as the dependent variables.

Results: After adjusting for age and sex, our analysis showed that poor tongue motility (odds ratio 17.23, 95% confidence interval 5.90–50.31, $P < 0.001$) and decreased Skeletal Muscle Mass Index (odds ratio 3.36, 95% confidence interval 1.41–7.99, $P = 0.006$) were significantly correlated with decreased swallowing function.

Conclusions: Decreased swallowing function was closely correlated with poor tongue motility, and this finding is similar to those of previous studies. However, the present results also show that decreased Skeletal Muscle Mass Index is a novel risk factor for dysphagia among older adults who require long-term care. **Geriatr Gerontol Int 2015; ••: ••–••.**

Keywords: dysphagia, long-term care, modified water swallowing test, Skeletal Muscle Mass Index, tongue motility.

Introduction

Japan has an aging rate of 25%, and a population that is characterized by longevity (compared with other countries), which has led to a significant amount of age-related research being carried out in the Japanese population.[1] Among this body of research, sarcopenia has been a topic of interest, as well as the accompanying decrease in muscle strength and motor function, as these factors can cause weakness and necessitate nursing care for older adults.[2,3] In previous studies, a systemic decrease in muscle mass was found to be a predictor of a low nutritional status[4] and decreased physical activity.[5] Furthermore, relationships between swallowing function and systemic disease, oral function, and nutritional status among older adults who require nursing care have also been reported.[6,7] However, few studies have evaluated the relationship between swallowing function and a systemic decreases in muscle mass.[8]

Previous studies have reported various risk factors for dysphagia among older adults who require nursing care. For example, if a systemic decrease in muscle mass decreases a person's swallowing function, their nutritional status could subsequently worsen, resulting in a

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vicious cycle. However, muscle mass can be increased through improvements in nutritional status and physical activity, and it might be an important parameter for evaluating swallowing rehabilitation in cases of dysphagia that are caused by aging.[9,10] Therefore, the present study used skeletal muscle mass (as evaluated using the Skeletal Muscle Index [SMI]) as a predictor of nutritional status and physical activity, and aimed to elucidate the relationship between SMI and dysphagia in these patients.[11]

Methods

Participants

The present study evaluated 399 men and women who were certified as requiring nursing care and were living in Omori town, Yokote city, Akita prefecture. The study tests were carried out on all inpatients at the Omori Hospital's disability or nursing care wards, residents of a special nursing home for the aged, three group homes for elderly patients with dementia, users of day service institutions and healthcare facilities for older adults in Omori town. All tests were carried out at each site or in the participants' homes. However, we excluded people who could not open their mouth or follow our instructions (e.g. due to reduced cognitive function). In addition, we excluded people who could not sit upright, lie in a supine position for a 5-min period or who had cardiac pacemakers. After excluding 144 participants with incomplete data or who could not complete our tests, we analyzed data from 255 participants for whom complete information were available regarding sex, age, case history (stroke, Parkinson's disease and dementia), Barthel Index, SMI, oral function test and modified water swallowing test results.

Ethical considerations

Informed consent was obtained from each participant or from their agent, such as their guardian or their family, before their participation in the present study. Each participant or their agent were fully informed regarding the purpose, nature and potential risks of the experiments; that participation was voluntary; and that they would not be placed at any disadvantage if they refused to participate in the study or withdrew before its completion. Participants' names and dates were recorded as numbers to prevent the identification of any individual. The study design was approved by the ethics committee of the Tokyo Metropolitan Institute of Gerontology (Issue #38 in 2009) and by the ethics committee of the Showa University School of Dentistry (Issue #2014-010 in 2014). All tests were carried out in accordance with the tenets of the Declaration of Helsinki, as revised in 2008.

Study design

The present study was carried out in February 2014. All swallowing and oral function tests were carried out by dental specialists who had 10 h of training in the study's tests, and experience in more than 10 cases; the evaluation criteria were calibrated to account for interinvestigator differences. In addition, nursing staff who provided daily support to the participants also supplied data regarding the participants' basic information, their assessments of activities of daily living and their nutritional assessments. Furthermore, to evaluate each participant's rinsing ability in daily life, we used assessments that were made by the nursing staff.

Basic information

Data regarding the participant's age, sex and medical history (stroke, Parkinson's disease and dementia) were obtained from the nursing staff.

Barthel Index

The participants' ability to carry out their activities of daily living was measured using the Barthel Index, with scores ranging from 0 to 100 points.[12]

SMI

The participants' body composition was measured using the InBody S10 system (Biospace, Seoul, Korea) by the bioelectrical impedance analysis (BIA) method, over a 5-min period. For this test, the participant either sits upright or lies in the supine position (body position does not affect the measured body composition). The InBody S10 system uses direct segmental multifrequency technology, and has previously been validated as having a strong correlation with muscle volume and fat mass, as measured via dual energy X-ray absorptiometry.[13] We did not test the SMI of participants who could not maintain their posture over a 5-min period or who had a cardiac pacemaker. The participants were categorized as having either normal or reduced muscle mass, and the lowest quintile was used as the cut-off value for the multivariate analysis, as in previous studies.[3,14]

Oral function

Occlusal contacts. We evaluated the state of molar occlusion using the methods that were described by Kikutani *et al.*[15] The occlusal support region from the first premolar tooth to the second molar tooth was defined as posterior molar occlusion, and a three-level assessment was made. Participants whose molar occlusion was only

established with the remaining teeth were evaluated as group A, participants who required dentures to maintain occlusion were evaluated as group B, and participants without dentures and who did not have molar occlusion were evaluated as group C. For our analysis, groups A and B were defined as the molar occlusion group, and group C was defined as the no occlusion group.

Tongue motility. Participants were asked to stick out their tongues, and asked to move their tongue from side to side (i.e. left to right), using previously described criteria.[16] Participants who could not obey instructions were examined by an investigator who stuck out their own tongue and asked the participant to imitate this action. If a participant's proglossis could pass beyond the dental arch and they could move their tongue from side to side, their tongue motility was defined as good; all other participants were defined as having poor tongue motility.

Rinsing ability. Participants who could rinse rhythmically and sequentially without leaking water from their lips were defined as have a good rinsing ability, and participants who could not successfully complete this task were defined as having poor rinsing ability.[16]

Mouth dryness. Mouth dryness was evaluated according to the clinical diagnosis classification scale that dentists use to evaluate the condition of the tongue mucosa.[17] This classification scale consists of four grades: non-dry mouth (0), saliva exhibits viscosity (1), saliva exhibits tiny bubbles on the tongue (2), and a dry tongue without viscosity and little or no saliva present (3). In the present study, we categorized dry mouth as grades 1–3, whereas the absence of dry mouth was defined as grade 0.

Swallowing function

We evaluated swallowing function using a modified water swallowing test (MWST), as previously described.[18] In short, 3 mL of cold water were poured into the floor of the participant's mouth using a 5-mL syringe, the participant was instructed to swallow, and their swallowing was scored (Table 1). If their score was ≥4, the test was repeated twice, and the lowest score was used as the test result. A score of 4 or 5 was defined as good swallowing function, and a score of ≤3 was defined as poor swallowing function. We did not test the swallowing function of participants who were at risk of severe dementia or whose general status was unknown.

Statistical analysis

Continuous variables were analyzed using the unpaired Mann–Whitney *U*-test, and categorical variables were analyzed using the χ^2-test. To identify the factors that were related to good or poor swallowing function, factors that were significant in the univariate analysis ($P < 0.25$) were selected as explanatory variables for the stepwise logistic-regression analyses, which were carried out with "good" or "poor" swallowing function as the dependent variables. SPSS Statistics (version 22, IBM Japan, Tokyo) was used for all analyses, and the significance level was set at $P < 0.05$.

Table 1 Modified water swallowing test score

Score 1	Inability to swallow with choking and/or breathing changes
Score 2	Swallowing occurred, but with breathing changes
Score 3	Swallowing occurred with no breathing changes, but with choking and/or wet hoarseness
Score 4	Swallowed successfully with no choking or wet hoarseness
Score 5	Furthermore to Score 4, additional deglutition (dry swallowing) occurred more than twice within 30 s

Results

The participants' clinical characteristics are shown in Table 2. This study included 58 men (mean age 83.6 ± 7.7 years) and 197 women (mean age 85.7 ± 5.9 years). Among the 255 participants, 91 participants (35.7%) had a history of stroke, seven participants (2.7%) had Parkinson's disease and 221 participants (86.7%) had dementia.

The mean value and frequency for each surveyed item was calculated and compared according to swallowing function (Table 3). In the univariate analysis, significant differences were observed for the Barthel Index ($P < 0.001$), SMI ($P < 0.001$), presence of stroke ($P = 0.016$), presence of dementia ($P = 0.028$), absence of molar occlusion ($P < 0.001$), poor tongue motility ($P < 0.001$), poor rinsing ability ($P < 0.001$) and SMI of less than the quintile ($P < 0.001$). Next, a stepwise logistic regression analysis was carried out using the factors that were associated with "good" or "poor" swallowing function as the explanatory variables ($P < 0.25$ in the univariate analysis; stroke, dementia, Barthel Index, the 2 molar occlusion groups, the 2 tongue motility values, the 2 rinsing values and the 2 SMI values). "Good" or "poor" swallowing function was set as the dependent variables, and analysis of the sex- and age-adjusted odds ratios (OR) showed that poor tongue motility (OR 17.23, 95% confidence interval [CI] 5.90–50.31, $P < 0.001$) and decreased SMI (OR 3.36, 95%

Table 2 Participants' characteristics and sex differences

		Male (n = 58)		Female (n = 197)		Total (n = 255)		
		Mean	SD	Mean	SD	Mean	SD	U-test P-value
Age (years)		83.6	7.7	85.7	5.9	85.2	6.4	0.052
Barthel Index		47.7	31.1	42.8	34.1	43.9	33.5	0.250
SMI (kg/m^2)		6.0	1.2	4.3	1.2	4.7	1.4	<0.001
		Applicable patients (%)	Overall (n)	Applicable patients (%)	Overall (n)	Applicable patients (%)	Overall (n)	χ^2-test P-value
Stroke	Onset	53.4%	31	30.5%	60	35.7%	91	0.001
Parkinson's disease	Onset	1.7%	1	3.0%	6	2.7%	7	0.588
Dementia	Onset	81.0%	47	88.3%	174	86.7%	221	0.151
Mouth dryness	Onset	86.2%	50	91.4%	180	90.2%	230	0.245
Occlusal contacts	Absence	25.9%	15	38.1%	75	35.3%	90	0.087
Tongue motility	Poor	15.5%	9	19.3%	38	18.4%	47	0.515
Rinsing ability	Poor	25.9%	15	27.4%	54	27.1%	69	0.815
SMI cut off	Poor	20.7%	12	19.8%	39	20.0%	51	0.881

SMI, Skeletal Muscle Index.

CI 1.41–7.99, $P = 0.006$) were significantly associated with decreased swallowing function (Table 4).

Discussion

The present study was designed to investigate the relationship between SMI (among older adults who require nursing care) and the known risk factors for dysphagia, which include age, oral function (occlusion state, rinsing ability and tongue motility), stroke, Parkinson's disease and dementia. The present results show that reduced tongue motility and reduced SMI are risk factors for dysphagia. In addition, we found that a reduction in SMI was a significant risk factor for reduced swallowing function.

Regarding the methods that are typically used to assess swallowing function, videofluoroscopic swallowing tests or videoendoscopic swallowing tests have frequently been used. However, these testing methods require special facilities, are carried out in an unnatural environment and are not suitable for general use, as they impose a significant burden on the participant. In contrast, the MWST can be carried out at the bedside, and Tohara *et al.* have reported that it has a sensitivity of 70% and a specificity of 88% for detecting aspiration.[18] We believe that the MWST is a useful screening test for detecting aspiration among home-dwelling and institutionalized older adults who require nursing care, because it is safe, requires minimal water volume and its validity has been confirmed. Therefore, we used the MWST as a method for assessing swallowing function, and were able to detect the presence or absence of dysphagia to a certain level of accuracy. We also evaluated the participants' cervical auscultation to confirm aspiration. In this context, cervical auscultation detects aspiration by listening with a stethoscope for sounds of swallowing that occur during deglutition, and for differences in respiration that occur before and after swallowing.[19]

The water swallowing test has several variations (3–100 mL) that are widely used. However, most of these tests look for a participant's cough, which can limit their ability to diagnose mild dysphagia. For example, the 3-mL water swallowing test might not identify mild dysphagic individuals (who can swallow 3 mL of water, but cannot drink liquid from a cup and require thickening agents), and these individuals could be common among elderly community-dwelling people who require long-term care. Therefore, another method is likely required if researchers wish to detect mild dysphagia.

Previous studies have reported that the loss of occlusion support leads to a decline in nutritional status, and might trigger dysphagia.[14] In addition, reduced physical function, degenerative disease and dietary intake have also been suggested as causes of poor nutrition.[20]

Table 3 Comparison of the survey items according to swallowing function

	Good (n = 215) Mean	SD	Poor (n = 40) Mean	SD	U-test P-value
Age (years)	85.2	6.4	85.3	6.3	0.877
Barthel index	48.1	32.3	21.5	30.9	<0.001
SMI (kg/m^2)	4.9	1.3	4.1	1.9	<0.001

		Applicable patients (%)	Overall (n)	Applicable patients (%)	Overall (n)	χ^2-test P-value
Stroke	Onset	32.6%	70	52.5%	21	0.016
Parkinson's disease	Onset	2.3%	5	5.0%	2	0.342
Dementia	Onset	84.7%	182	97.5%	39	0.028
Mouth dryness	Onset	90.7%	195	87.5%	35	0.532
Occlusal contacts	Absence	30.2%	65	62.5%	25	<0.001
Tongue motility	Poor	12.1%	26	52.5%	21	<0.001
Rinsing ability	Poor	20.0%	43	65.0%	26	<0.001
SMI cut off	Poor	14.9%	32	47.5%	19	<0.001

SMI, Skeletal Muscle Index.

Table 4 Stepwise procedure in logistic regression analysis of risk factors for swallowing function

		Univariate OR	95% CI	P-value	Multivariate OR	95% CI	P-value
Sex	0: Male 1: Female	0.74	0.34–1.59	0.436			
Age		1.00	0.95–1.06	0.925			
Stroke	0: Absence 1: Onset	2.29	1.16–4.53	0.017			
Dementia	0: Absence 1: Onset	7.07	0.94–53.27	0.058			
Barthel Index		0.97	0.96–0.98	<0.001			
Occlusal contacts	0: Onset 1: Absence	3.85	1.90–7.77	<0.001			
Tongue motility	0: Good 1: Poor	25.75	9.23–71.79	<0.001	17.23	5.90–50.31	<0.001
Rinsing ability	0: Good 1: Poor	7.43	3.58–15.42	<0.001			
SMI cut off	0: Good 1: Poor	6.04	2.89–12.62	<0.001	3.36	1.41–7.99	0.006

Left: Univariate analysis using logistic regression analysis. Right: Multivariate analysis using logistic regression analysis.
CI, confidence interval; OR, odds ratio; SMI, Skeletal Muscle Index.

Furthermore, mastication function, which encompasses the number of remaining teeth, number of functional teeth and general oral health, is also considered a major factor.[21,22] However, we did not find a significant relationship between swallowing function and the presence or absence of molar occlusion. In contrast, the presence or absence of molar occlusion has been reported to have a major impact on mastication function, and is thought to play a major role in regulating swallowing function.[23] However, we believe that this association was absent in the present study, because most of our participants were residing in nursing care institutions and were receiving food that was appropriate for their level of mastication function. Furthermore, the MWST cannot assess mastication function, which might have masked any association between swallowing function and mastication function.

Many methods exist for assessing mouth dryness, although our assessments were made by visual examination of the oral cavity by a dentist.[17] An association between mouth dryness and dysphagia has been reported using the Repetitive Saliva Swallowing Test, although no such association was observed in our study.[24] We believe that this discrepancy is due to the fact that the MWST was carried out by pouring 3 mL of cold water onto the floor of the oral cavity and asking the participant to swallow, which would have minimized the effect of mouth dryness, compared with that which is experienced during the Repetitive Saliva Swallowing Test, where the person swallows his or her own saliva.

Sato *et al.* have evaluated Alzheimer's disease patients with dementia in aged care facilities, and reported that poor rinsing was a risk factor for dysphagia.[16] In that study, a MWST score of ≤3 was defined as dysphagia

(we used the same criterion), but we found that poor rinsing was not a risk factor for reduced swallowing function.

Tongue motility is very important for the formation of a food bolus and transfer during the oral phase, and is also a key factor in swallowing.[25] As tongue motility is strongly related to tongue pressure and muscle mass, Yoshida *et al.* have reported that tongue pressure is significantly reduced in patients with dysphagia.[26] In addition, Okayama *et al.* have evaluated tongue pressure and thickness among elderly persons who required nursing care, and they reported that participants with dysphagia had low values for tongue pressure and thickness, and that there was an association between tongue motility and dysphagia.[27] The present findings support the conclusion that poor tongue motility is a risk factor for reduced swallowing function. Therefore, sticking out the tongue can be used as a simple screening method for dysphagia, which is another key finding of the present study. Furthermore, reduced tongue thickness and pressure is significantly associated with the period of nursing care and body mass index, which indicates that decreases in muscle mass can occur both systemically and specifically in the tongue.[27] In addition, reduced swallowing function occurs when less muscle mass is present in the muscles that are involved in swallowing food. Therefore, in frail elderly patients with dysphagia, difficulties in closing the pharyngeal vestibule, failure to transfer food with the tongue and delays in hyoid bone movement should be considered.[28] Finally, Tamura *et al.* have measured tongue muscle thickness in elderly patients using an ultrasound diagnostic device, and they reported that nutritional status also influenced tongue muscle thickness.[29]

In the present study, a reduced SMI was a significant risk factor for reduced swallowing function. Interestingly, much research and debate exists regarding the precise definition and diagnostic criteria for sarcopenia, which have yet to be standardized.[2,3] However, several published articles[3] have stated that the broad diagnostic criteria for sarcopenia include both a reduction in muscle mass, and a reduction in muscle strength and physical function. Nevertheless, the measurement of muscle mass is indispensable in all of the criteria. Various methods have been used to evaluate muscle mass, including computed tomography, magnetic resonance imaging, dual X-ray absorptiometry and the BIA method. However, after considering the effects of X-ray exposure on our participants and the available facilities, we selected the BIA method, which can be carried out in the seated upright position or while in the supine position. The Asian Working Groups for Sarcopenia recommends evaluating height-adjusted skeletal muscle mass, with suggested cut-off values of 7.0 kg/m^2 in men and 5.7 kg/m^2 in women when BIA is used.[3] However, these cut-off values were not suitable for the present population, as we only evaluated older adults who required long-term care, and the use of these cut-off values would have included most of the participants. Furthermore, Newmann *et al.* used the lowest quintile as their cut-off value, and the Asian Working Groups for Sarcopenia recommends using the lower quintile or two standard deviations below the mean muscle mass of the young reference group.[14] Therefore, based on our target population, we selected the lowest quintile as the SMI cut-off value among older adults who require long-term care.

Muscles undergo repetitive cycles of protein synthesis and breakdown, and muscle mass is known to decrease during aging as the rate of breakdown exceeds the rate of synthesis; the decrease in muscle mass occurs when this imbalance becomes severe. Nutritional habits, such as the consumption amino acids and vitamin D, are crucial to maintaining protein synthesis, and the worsened nutritional status that occurs during aging affects the muscle mass of the whole body, including the muscles that are involved in swallowing. Thus, these changes can lead to a reduction in swallowing function. Kuroda *et al.* have used the graded water swallowing test for assessing swallowing function, and reported that dysphagia among elderly patients was correlated with upper arm circumference, which also suggests that decrease in muscle mass is related to dysphagia.[8] In addition, we used the BIA method, which is more accurate than the upper arm circumference for assessing muscle mass (as it measures lean body mass), and were able to more clearly highlight the relationship between muscle mass and dysphagia.

The present results show that a cycle exists whereby a reduction in nutritional status occurs as a result of a reduction in swallowing function, which in turn leads to a reduction in SMI and tongue muscle mass, and these reductions result in a further reduction in swallowing function. In the future, given the increasing average lifespan and the development of disease prevention methods, we predict an increased number of elderly patients who experience a decline in swallowing function that does not have a clear cause (e.g. stroke) and proceeds subclinically. Furthermore, the present results show that oral function assessment methods and systemic muscle mass assessment (e.g. through SMI) can be used to effectively screen for declining swallowing function as a result of aging and poor nutrition. Using these screening methods, patients can be identified and provided with appropriate nutritional therapy and rehabilitation. Furthermore, these methods might be relevant and easy to use for elderly persons and their caregivers, and we hope that these findings can be used to prevent the decline in swallowing function among elderly persons.

The present study used a cross-sectional design, and we are unable to comment on the causality of the

relationship between SMI and swallowing function. However, as we carried out our analysis with "good" or "poor" swallowing function as the dependent variables, we were able to show that a reduction in SMI was a significant risk factor for reduced swallowing function. Nevertheless, a longitudinal study is required to determine whether reduced SMI can cause a decline in swallowing function. In addition, 144 people were excluded from our analysis because they were incapable or unwilling to undergo our testing, and it is possible that these exclusions affected our findings, although these exclusion criteria are common among our target population. Nevertheless, our finding that numerous participants could not undergo the MWST or SMI measurements is relevant, as it indicates that these indices should be adapted to incorporate these people in the future. Furthermore, although we evaluated the swallowing function, oral function and SMI of elderly participants who required nursing care, we did not study the relationship between SMI and the mass of the muscles that are involved in mastication and swallowing, such as the tongue, masseter or suprahyoid muscles. Moreover, we did not investigate the relationship between SMI and the quality of these muscles. Therefore, future studies should examine the relationship between oral function (swallowing and mastication functions) and systemic muscle state in new participants, using BIA and an ultrasonographic diagnostic device, in order to evaluate the association between systemic muscle mass and that of the muscles that are involved in mastication.

In conclusion, based on our analysis of the risk factors for dysphagia among elderly participants who required nursing care, a reduced SMI was a statistically significant risk factor for dysphagia, even after adjusting for age, oral function (occlusion state, rinsing ability, and tongue motility), stroke, Parkinson's disease and dementia.

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Disclosure statement

No potential conflicts of interest were disclosed.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Relationship between skeletal muscle mass and swallowing function in patients with Alzheimer's disease

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Aim: The present study verified the hypothesis that decreased skeletal muscle in older adults with Alzheimer's disease is related to Alzheimer's disease progression and decreased oral or swallowing function.

Methods: We investigated 232 patients with Alzheimer's disease (31 men, 201 women, average age 85.4 ± 5.9 years) in two regions in Japan. The patients provided basic information (sex and age), and were assessed for skeletal muscle index, dementia severity (clinical dementia rating), activities of daily living, nutritional status, oral status and swallowing function.

Results: Stratification by clinical dementia rating was as follows: clinical dementia rating 0.5:21 patients (9.0%), clinical dementia rating 1:85 patients (36.6%), clinical dementia rating 2:88 patients (37.9%) and clinical dementia rating 3:38 patients (16.3%). Alzheimer's disease severity was significantly related to skeletal muscle index. Logistic regression analysis showed that clinical dementia rating 3 (odds ratio 11.68, 95% confidence interval 4.52–30.20), body mass index < 18.5 (odds ratio 3.18, 95% confidence interval 1.27–8.00), calf circumference <30.5 cm (odds ratio 9.33, 95% confidence interval 2.01–43.27) and poor swallowing function (odds ratio 4.93, 95% confidence interval 1.10–22.04) had a significant effect on decreased skeletal muscle index.

Conclusions: Therefore, decreased skeletal muscle mass in patients with Alzheimer's disease requires strategies to manage swallowing dysfunction. **Geriatr Gerontol Int 2016; ••: ••–••**

Keywords: Alzheimer's disease, dysphagia, sarcopenia, skeletal muscle mass, swallowing function.

Introduction

Recently, the number of patients with dementia has increased worldwide, and dementia has become the second leading cause of disease requiring long-term care in Japan.[1,2] Alzheimer's disease (AD) is expected to increase among patients with dementia in the future; therefore, there is a need for management strategies.

Decreased skeletal muscle mass has been attracting attention as a predictor for decreased physical function in a recent sarcopenia study.[3,4] A previous study reported that AD progression was correlated with lean mass, and considered that patients with AD were at a risk of lower physical functioning caused by decreased skeletal muscle mass.[5] However, this was studied in mild AD, and has not been studied in moderate or severe AD.

Also, another previous study reported that sarcopenia was related to oral or swallowing function in community-dwelling or hospitalized older adults.[6,7] Sato *et al.* reported decreased oral and swallowing functions among patients with severe AD.[8] Therefore, we hypothesized that decreased skeletal muscle mass in older adults with AD is related to AD progression and decreased oral or swallowing function. It is important to understand the relationship between sarcopenia and oral and swallowing functions in patients with AD, and this relationship is considered to be a problem directly connected with the quality of life of the patient with AD for maintaining the nourishment state. If decreased oral and swallowing functions are specifically related to decreased skeletal muscle mass, maintaining or improving oral and swallowing functions through various treatments, such as dental treatments, dysphagia rehabilitation and compensatory

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techniques (e.g. modification of food forms), might maintain the skeletal muscle mass, physical function and quality of life of patients with AD. However, this has not yet been investigated. To verify our hypothesis, we investigated 284 patients with very mild to severe AD.

Methods

Participants

The present study evaluated 284 older patients diagnosed with AD by neurologists. They had been certified as requiring long-term care, and were living in Omori town, Yokote city, Akita prefecture and Yokohama city, Kanagawa prefecture, Japan. Table 1 shows patient characteristics and facilities that collected the data. All tests were carried out at each facility or at the participants' home.

We excluded patients who could not follow our instructions because of severe aphasia or could not open their mouth because of factors, such as of temporomandibular joint problems. Furthermore, the patients with cerebrovascular or Parkinson's disease were excluded for differentiating between AD and other dementia, such as vascular dementia and dementia with Lewy bodies. Additionally, we excluded patients with cardiac pacemakers and who could not remain in either a sitting or supine position for a 5-min period. After excluding 52 participants with incomplete data or who could not complete our tests, we analyzed data from 232 participants (31 men, 201 women, average age 85.4±5.9 years) for whom data regarding basic information, dementia severity, skeletal muscle index (SMI), physical function assessment, nutrition status, oral status and function, and swallowing test results were available.

Dementia diagnosis was carried out in accordance with the Diagnostic and Statistical Manual of Mental Disorders, Third Edition, Text Revision.[9] Additionally, AD was diagnosed in accordance with the criteria issued by the National Institute of Neurological and Communicative Disorders and Stroke and the Alzheimer's Disease and Related Disorders Association,[10] and diagnostically classified as the group having a Hachinski Ischemic Score[11] of 4 or less. Mixed dementia and other patients with dementia were excluded as participants of the present study.

Ethical considerations

Informed consent was obtained from each participant, or from their guardian or family before participation in this study. Each participant or their agent was fully informed regarding the purpose, nature and potential risks of the experiments; they were also informed that their participation was voluntary, and that they would not be placed at any disadvantage if they refused to participate in the study or withdrew before its completion. The participants' names and dates were recorded as numbers to prevent the identification of any individual. The study design was

Table 1 Patient characteristics and facilities that collected the data

	Age (years)	*P*-value	Total		Hospitals' disability or nursing care wards		Healthcare facilities for elderly		Special nursing home for the aged		Day service institutions or patients' home		Group homes for elderly patients with dementia	
Men	84.7±5.6	0.514	31	100.0%	5	16.1%	3	9.7%	4	12.9%	5	16.1%	14	45.2%
Women	85.5±6.0		201	100.0%	7	3.5%	15	7.5%	36	17.9%	14	7.0%	129	64.2%
Total	85.4±5.9		232	100.0%	12	5.2%	18	7.8%	40	17.2%	19	8.2%	143	61.6%

approved by the ethics committee of the Tokyo Metropolitan Institute of Gerontology (Issue #38 in 2009) and by the ethics committee of the Showa University School of Dentistry (Issue #2014-010 in 2014). All tests were carried out in accordance with the tenets of the Declaration of Helsinki, as revised in 2008.

Study design

The present study was carried out from September 2013 to February 2014. Oral status and function tests were carried out by dental specialists who had more than 10 h of training for the study and who had experience in more than 10 cases; the evaluation criteria were calibrated to account for interinvestigator differences. Furthermore, the nursing staff providing daily support to the participants also supplied data regarding the participants' basic information, dementia severity, assessments of activities of daily living and nutritional status.

Basic information

Data regarding the participant's age and sex were obtained from the nursing staff.

Dementia severity

Dementia severity was classified by the clinical dementia rating (CDR) as very mild (CDR0.5), mild (CDR1), moderate (CDR2) or severe (CDR3).[12] For multivariate analysis, we classified the patients into a very mild–moderate group and a severe group using the methods described by Sato *et al.*[8]

SMI

The participants' body compositions were measured using the InBody S10 system (Biospace, Seoul, Korea) using the bioelectrical impedance analysis method over a 5-min period.[13] For this test, the participants remained in either a sitting or supine position (body position does not affect body composition measurements). The InBody S10 system uses direct segmental multifrequency technology, and its strong correlation with muscle volume and fat mass has been validated, as measured by dual energy X-ray absorptiometry. The extremity muscle mass (kg) was determined from the sum of the upper and lower extremities. We then divided the measured extremity muscle mass by the squared height (m conversion) of the patient, and the adjusted extremity muscle mass was used as SMI.

We did not test the SMI of participants unable to maintain their posture over a 5-min period or those with cardiac pacemakers. The participants were categorized as having either normal or decreased muscle mass, and the sex-specific lowest quintile was used as the cut-off value (men 5.3 kg/m^2, women 3.9 kg/m^2) for multivariate analysis, as described in previous studies.[14]

Physical function assessment

The participants' ability to carry out activities of daily living was measured using the Barthel Index (BI), with scores ranging from 0 to 100 points.[15]

Nutrition status

Body mass index: We divided the bodyweight (kg) by the squared height (m conversion) for body mass index (BMI). For multivariate analysis, BMI values were classified into two groups using the cut-off value (18.5 kg/m^2) as described by Woo *et al.*[16]

Mini Nutritional Assessment Short-Form: The Mini Nutritional Assessment Short-Form (MNA-SF) was classified into two groups using the cut-off value (score 8) as described by Kikutani *et al.*[17]

Calf circumference: To measure calf circumference (CC), the dominant foot was measured. We made participants sit with a knee angle of 90° and the sole on the ground. The thickest part of the calf was measured with a measuring tape. CC was approximated for participants unable to remain in a sitting posture. CC values were classified into two groups using the cut-off value (30.5 cm) as described by Bonnefoy *et al.*[18]

Oral status and function: Occlusal contacts and tongue function were investigated, because they play important roles in mastication and swallowing.

Occlusal contacts

We evaluated molar occlusion status using the methods described by Kikutani *et al.*[17] The occlusal support region from the first premolar tooth to second molar tooth was defined as the posterior molar occlusion, and a two-level assessment was made. Participants whose molar occlusion was only established with their remaining teeth and/or dentures were evaluated as the "present" group, and participants without dentures and not having molar occlusion were evaluated as the "absent" group.

Tongue function

Participants were asked to stick out their tongues and to move their tongues from side to side (i.e. left to right), using previously described criteria.[8] Participants unable to obey these instructions were examined by an investigator who stuck out their tongue and asked the participants to imitate. If a participant's proglossis could extend past the dental arch, their tongue function was defined as "good." All other participants were defined as having a "poor" tongue function.

Swallowing function

We evaluated swallowing function using a modified water swallowing test (MWST), as previously described.[19] In brief, 3 mL of cold water was poured onto the floor of the participant's mouth using a 5 mL syringe, the participant