Table 1 Characteristics of study participants

	Men Sarcopenia (n = 139)	No sarcopenia (n = 838)	P	Women Sarcopenia (n = 220)	No sarcopenia (n = 774)	P
Age (years)	78.4 ± 5.5	72.2 ± 5.0	<0.001	76.2 ± 5.8	71.8 ± 4.9	<0.001
Height (cm)	160.0 ± 5.6	164.9 ± 5.5	<0.001	148.2 ± 5.6	152.3 ± 5.1	<0.001
Weight (kg)	54.1 ± 7.2	64.3 ± 8.0	<0.001	46.4 ± 5.7	52.9 ± 7.6	<0.001
BMI (kg/m^2)	21.1 ± 2.5	23.6 ± 2.6	<0.001	21.1 ± 2.6	22.8 ± 3.2	<0.001
Grip strength (kg)	27.5 ± 4.3	36.0 ± 5.3	<0.001	18.4 ± 3.2	23.6 ± 3.3	<0.001
Thigh circumference (cm)	38.8 ± 3.5	42.4 ± 3.3	<0.001	38.9 ± 3.4	41.7 ± 4.0	<0.001
Calf circumference (cm)	32.8 ± 2.3	36.3 ± 2.5	<0.001	32.1 ± 2.1	34.5 ± 2.7	<0.001
Upper arm circumference (cm)	25.7 ± 2.5	28.4 ± 2.4	<0.001	25.7 ± 2.3	27.3 ± 2.9	<0.001
SMI (kg/m^2)	6.34 ± 0.48	7.44 ± 0.58	<0.001	5.25 ± 0.41	6.02 ± 0.60	<0.001
Usual gait speed (m/s)	1.28 ± 0.24	1.51 ± 0.24	<0.001	1.26 ± 0.26	1.51 ± 0.23	<0.001
Physical activity (MET-minutes/week)	1813 (720, 3504)	2540 (1200, 4746)	0.008	1341 (33, 3209)	2587 (1092, 4824)	<0.001
Chronic conditions (%)						
Hypertension	51.1	46.5	0.32	45.9	38.1	0.04
Diabetes mellitus	18.0	14.9	0.36	8.2	8.9	0.73
Stroke	12.2	6.4	0.01	5.9	4.4	0.35
Osteoporosis	4.3	1.4	0.02	32.7	16.6	<0.001
Use of medications (%)						
Statins	18.7	17.4	0.71	29.1	30.6	0.66
Antihypertensives	53.2	45.1	0.08	42.7	36.2	0.08
Albumin (g/dL)	4.37 ± 0.26	4.43 ± 0.23	0.005	4.39 0.23	4.43 ± 0.22	0.04

Values are shown as mean ± standard deviation except for physical activity which was not normally distributed and therefore the mean value and inter-quartile range were shown. BMI, body mass index; MET, Metabolic Equivalent; SMI, skeletal muscle mass index.

Table 2 Pearson correlations between components of sarcopenia and six candidate variables

	Age	BMI	Grip strength	Thigh circumference	Calf circumference	Upper arm circumference
Men						
SMI	−0.33***	0.70***	0.49***	0.70***	0.78***	0.69***
Grip strength	−0.46***	0.21***	1	0.27***	0.35***	0.35***
Usual gait speed	−0.35***	0.007	0.29***	0.06	0.13***	0.10**
Women						
SMI	−0.24***	0.69***	0.50***	0.67***	0.75***	0.65***
Grip strength	−0.36***	0.16***	1	0.22***	0.33***	0.21***
Usual gait speed	−0.42***	−0.08**	0.36***	0.01	0.12***	−0.02

*, **, ***Significance at 0.1%, 1%, 5% level, respectively. BMI, body mass index; SMI, skeletal muscle mass index.

sarcopenia in multiple logistic regression (restricted model). These findings were consistent in both sexes. The area under the ROC curve of the full model was 0.940 (95% confidence interval [CI] 0.920–0.959) for men and 0.910 (95% CI 0.888–0.932) for women, showing excellent discriminative ability. The area under the ROC curve of the restricted model (0.939 with 95% CI 0.918–0.958 for men and 0.909 with 95% CI 0.887–0.931 for women) was not significantly different from that of the full model in both sexes ($P = 0.71$ for men, 0.43 for women). Assessment of internal validity showed that discriminative ability of the restricted model is expected to be good in similar populations (area 0.937 for men, 0.907 for women).

The final model was presented as a score chart in each sex (Table 4). The use of the score chart with two hypothetical patients is shown in Table S1. The discriminative ability of the score chart was comparable with those of the full and restricted models in each sex (area 0.935 for men, 0.908 for women; Fig. S1).

Figure 1 shows the estimated probabilities corresponding to the sum scores as calculated with the score chart in Table 4, and the sensitivity and specificity using the sum scores as cut-off values. The sum score that maximized the sum of sensitivity and specificity was 105 for men and 120 for women. The corresponding sensitivity, specificity, positive and negative predictive values, and positive and negative likelihood ratios were 84.9%, 88.2%, 54.4% and 97.2%, and 7.19 and 0.17 for men, and 75.5%, 92.0%, 72.8% and 93.0%, and 9.44 and 0.27 for women, respectively.

Sensitivity analysis

Because there are no established reference cut-off values for grip strength and usual gait speed in Japanese older adults, we used the lowest quintiles of the observed distributions to classify low muscle strength and low physical performance. As sensitivity analysis, we used the lowest deciles of grip strength and usual gait speed to capture participants with more severely impaired muscle function (i.e. strength or performance), and defined them as having sarcopenia, with the same cut-off values for muscle mass as in the main analysis. We then examined the model performance with all six variables and with the same set of three variables as selected in the main analysis (age, grip strength and calf circumference). The cut-off value of grip strength was 27 kg for men and 17 kg for women, and that of usual gait speed was 1.16 m/s for men and 1.13 m/s for women. The prevalence of sarcopenia was 9.6% in men and 12.7% in women. Both models performed well (area of the full model: 0.932 for men, 0.919 for women; area for the restricted model; 0.931 for men, 0.918 for women; Figure S2).

Discussion

To estimate the probability of sarcopenia in functionally independent, community-dwelling Japanese older adults, we created multivariate models based on the three selected variables (age, grip strength and calf circumferences), and found excellent discrimination ability of the models: the area under the curve was 0.939 for men and 0.909 for women. We constructed a score chart in each sex so that the approximate probability of sarcopenia could be easily obtained from the values of the three variables, and confirmed that the score charts also had excellent discrimination.

Although our multivariate models had excellent discrimination capacity, the model's sensitivity and specificity at candidate diagnostic thresholds must be assessed to judge the model's clinical usefulness.[18] Higher sensitivity can be achieved at the expense of lower specificity and vice versa. For example, if higher sensitivity was desired; for example, 90%, then the cut-off score would be 101 for men and 104 for women, and the specificity would be lower at 82.2% for men and 70.4% for women. Higher specificity, 90%, could be achieved with the higher cut-off score of 107 for men

Table 3 Unadjusted and adjusted associations between sarcopenia and the variables

Variables	Men						Women					
	Bivariate		Multivariate (full model)		Multivariate (restricted model)		Bivariate		Multivariate (full model)		Multivariate (restricted model)	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Age	1.21 (1.17–1.26)	<0.001	1.07 (1.02, 1.12)	0.008	1.07 (1.02, 1.12)	0.008	1.16 (1.13, 1.20)	<0.001	1.10 (1.05, 1.14)	<0.001	1.09 (1.04, 1.13)	<0.001
BMI	0.68 (0.63–0.74)	<0.001	0.96 (0.78, 1.18)	0.69			0.82 (0.78, 0.87)	<0.001	0.86 (0.74, 1.00)	0.05		
Grip strength	0.71 (0.67, 0.75)	<0.001	0.73 (0.68, 0.78)	<0.001	0.73 (0.68, 0.79)	<.001	0.57 (0.53, 0.62)	<0.001	0.58 (0.53, 0.64)	<0.001	0.59 (0.55, 0.65)	<0.001
Thigh circumference	0.73 (0.69, 0.78)	<0.001	1.05 (0.91, 1.21)	0.53			0.82 (0.78, 0.86)	<0.001	0.94 (0.85, 1.04)	0.24		
Calf circumference	0.57 (0.52, 0.63)	<0.001	0.62 (0.53, 0.73)	<0.001	0.62 (0.56, 0.69)	<.001	0.68 (0.64, 0.74)	<0.001	0.80 (0.69, 0.91)	<0.001	0.71 (0.65, 0.78)	<0.001
Upper arm circumference	0.63 (0.57, 0.68)	<0.001	0.97 (0.82, 1.15)	0.71			0.80 (0.75, 0.85)	<0.001	1.15 (0.98, 1.35)	0.10		

BMI, body mass index; CI, confidence interval; OR, odds ratio.

and 118 for women, resulting in lower sensitivity of 77.7% for men and 76.8% for women (Fig. 1). The trade-off between sensitivity and specificity depends on the cost of incorrect classification of those with sarcopenia relative to the cost of incorrect classification of those without sarcopenia. The cost of incorrect answers would vary according to the clinical or research scenario and personal preferences.[16,17]

Several observations suggested that the selection of three variables (age, grip strength and calf circumference) was not based on chance. First, sarcopenia was classified based on muscle mass, muscle strength and physical performance, all of which were significantly correlated with the three variables. Calf circumference was used to represent muscle mass, considering the highest correlation between SMI and calf circumference among the variables considered. A strong correlation between calf circumference and muscle mass was previously shown in Caucasian older women who were on average more obese than women in the present.[19] Grip strength was used as an indicator of muscle strength. Usual gait speed, a measure of physical performance, was significantly correlated with each of the three variables. Second, sarcopenia was associated with each of the three variables in both bivariate and multivariate analyses in each sex, and *P*-values for these findings were comfortably below 0.01. Third, the models with the three variables had excellent discrimination for sarcopenia based on more stringent cut-off levels for grip strength and usual gait speed.

There have been several prior attempts at estimating the quantity of muscle mass using a variety of variables with varying degrees of accuracy.[20–23] Although these studies were inspired by the desire to facilitate the diagnosis of sarcopenia, recently developed definitions of sarcopenia entail the presence of low muscle function, as well as muscle mass.[1,24] The present study developed statistical models with high accuracy for sarcopenia, which was defined based on muscle mass and muscle function.

This study had several limitations. First, the measurement method of usual gait speed was different from those used by the majority of previous studies.[25] The measurement method used in the present study required the participant to walk 3 m before the measurement started. An attribute of this method is that it is less affected by the gait initiation phase where age-related changes independent of gait speed occur.[26,27] This method has been widely used in Japan,[9,28] and has been shown to be reliable,[10] but because it starts measuring after the gait initiation phase, it tends to yield higher values than those obtained with other measurement methods, such as usual gait speed over a 4- or 6-m course,[25] making direct comparison difficult. Second, the current analysis was carried out on data from Japanese older adults, and our findings therefore might not

Table 4 Score charts for estimated probability of sarcopenia

Variables	Value													
Men														
Age			<66	66	68	70	72	74	76	78	80	82	84	86≦
Score			0	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11
Grip strength		<20	20	23	26	29	32	35	38	41	44	47	50≦	
Score		+99	+90	+81	+72	+63	+54	+45	+36	+27	+18	+9	0	
Calf circumference	<26	26	28	30	32	34	36	38	40	42≦				
Score	+81	+72	+63	+54	+45	+36	+27	+18	+9	0				
Estimated individual probability of sarcopenia														
Sum score	70	80	90	95	100	105	110	115	120	125	130	135	140	145
Probability (%)	1	2	5	8	13	19	28	39	51	64	74	83	89	93
Women														
Age			<66	66	68	70	72	74	76	78	80	82	84	86≦
Score			0	+2	+4	+6	+8	+10	+12	+14	+16	+18	+20	+22
Grip strength		<14	14	16	18	20	22	24	26	28	30	32	34≦	
Score		+110	+100	+90	+80	+70	+60	+50	+40	+30	+20	+10	0	
Calf leg circumference			<26	26	28	30	32	34	36	38	40	42≦		
Score			+63	+56	+49	+42	+35	+28	+21	+14	+7	0		
Estimated individual probability of sarcopenia														
Sum score	80	90	95	100	105	110	115	120	125	130	135	140	145	150
Probability (%)	1	3	5	8	12	19	28	39	51	63	74	82	88	93

Values for each variable are given with such intervals that the scores show small steps, and scores for intermediate values can be estimated by linear interpolation. The exact formula to calculate the scores are as follows: score in men, 0.62 × (age – 64) – 3.09 × (grip strength – 50) – 4.64 × (calf circumference – 42); score in women, 0.80 × (age – 64) – 5.09 × (grip strength – 34) – 3.28 × (calf circumference – 42). The corresponding probabilities of sarcopenia are calculated with the following formulae: probability in men, $1 / [1 + e^{-(\text{sum score} / 10-11.9)}]$; probability in women, $1 / [1 + e^{-(\text{sum score} / 10-12.5)}]$.

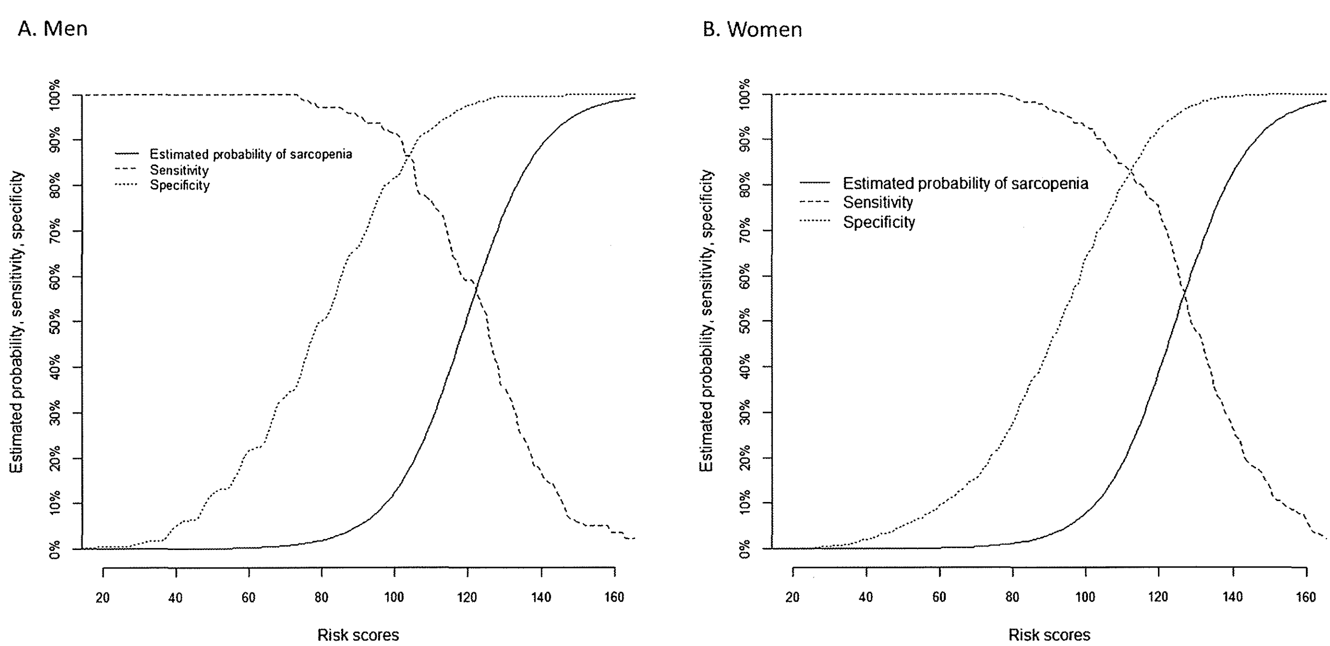

Figure 1 Estimated probabilities, sensitivity and specificity corresponding to sum scores. The sum scores and corresponding estimated probabilities are read from Table 3.

be applicable to populations of other race/ethnicity or in other countries. Similarly, caution should be exercised in projecting beyond the range of our data. For example, the obese were underrepresented in our data, and the performance of our models was not assessed for the obese. However, the present findings suggest that three variables, namely age, grip strength and calf circumference, should be considered for inclusion in the development of sarcopenia screening in other populations. Third, although the internal validity was good (i.e. the models would perform well in a similar population), assessment of external validity is still warranted to determine whether the results can be extended to other Japanese populations. Finally, we could not exclude the possibility of the healthy volunteer effect (i.e. volunteers for clinical studies tend to be healthier than the general population). Although participants were randomly selected from the resident register, participation was voluntary and the response rate was approximately 17%. However, the sensitivity analysis showed that the models' ability to estimate the probability of sarcopenia remained excellent when participants with more severely impaired muscle function were categorized as having sarcopenia.

In conclusion, we showed that the presence of sarcopenia in older adults could be detected with high accuracy using three easily obtainable variables. Importantly, we derived the models from a functionally independent, community-dwelling population. Functionally independent older adults with sarcopenia are good candidates for interventions to prevent further physical limitations, given their potential for regaining muscle mass and restoration of muscle function. The score charts we developed can be used as an effective screening tool and help identify functionally independent older adults with sarcopenia.

Acknowledgments

This work was supported by a Health and Labor Sciences Research Grant (H24-Choju-Ippan-002) from the Ministry of Health, Labor, and Welfare of Japan. The authors thank the staff members and participants of the Kashiwa study and the following individuals for helping with the acquisition of data: Dr Yoshiya Oishi PhD DDS, Oishi Dental Clinic. Yuki Ohara, Tokyo Metropolitan Geriatric Institute of Gerontology; Dr Noriaki Takahashi and Dr Hiroyasu Furuya, The Nippon Dental University; Seigo Mitsutake, Tokyo Metropolitan Institute of Gerontology; Mr Masashi Suzuki, Institute of Gerontology, The University of Tokyo; and staff members of The Institute of Healthcare Innovation Project, The University of Tokyo.

Disclosure statement

The authors declare no conflict of interest.

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's web-site:

Figure S1 Receiver operating characteristic curves of models estimating the probability of sarcopenia.
Figure S2 Receiver operating characteristic curves of models estimating the probability of sarcopenia based on different cut-off values for grip strength and usual gait speed.
Table S1 Application of Score Chart in two hypothetical patients.

One-leg standing time with eyes open: comparison between the mouth-opened and mouth-closed conditions

Mitsuyoshi Yoshida[1], Yayoi Kanehisa[2], Yoshie Ozaki[3], Yasuyuki Iwasa[4], Takaki Fukuizumi[5], Takeshi Kikutani[6]

[1]Dental Department, Hiroshima City Rehabilitation Hospital, Hiroshima, Japan, [2]Department of Oral Functional Management, School of Oral Health Sciences Kyushu Dental University, Kitakyushu, Japan, [3]Department of Dentistry, Saiseikai Yahata General Hospital, Kitakyushu, Japan, [4]Department of Dentistry, Haradoi Hospital, Fukuoka, Japan, [5]Laboratory of Social Dentistry, Kyushu Dental University, Kitakyushu, Japan, [6]Division of Clinical Oral Rehabilitation, The Nippon Dental University Graduate School of Life Dentistry, Tokyo, Japan

Objective: Many studies report a significant relationship between the one-leg standing time with the eyes open and the occlusal relationship. To determine the association between proprioception (the periodontal membrane vs muscle spindle) to the one-leg standing time, the authors compared the one-leg standing time with eyes open between mouth-opened and mouth-closed conditions.
Methods: The study participants were 107 healthy, elderly patients. The authors measured the one-leg standing time with eyes open between mouth-opened and mouth-closed conditions.
Results: The one-leg standing time was significantly shorter with the mouth opened (21.1±19.1 seconds) than with the mouth closed (25.1±21.4 seconds). Patients whose one-leg standing time was equal or shorter with the mouth opened than with the mouth closed were not different from the other patients with regard to age, handgrip strength, BMI, and the number of remaining teeth.
Discussion: The vertical mandibular position may affect body balance.

Keywords: Handgrip strength, One leg standing time with eyes open, Remaining teeth

Introduction

In today's aging society, a variety of initiatives have been proposed to address a major focus in primary care: falls and fractures prevention. The World Health Organization (WHO) declared the 2000–2010 decade as the Bone and Joint Decade.[1] In response, Japan has taken active steps towards preventing primary nursing care and nursing care risks due to locomotive difficulty. This is fueled by new concepts of the locomotive syndrome. A method of assessing the risk of falling is the one-leg standing time with the eyes open.[2] Several reports suggest that this standing time is significantly related to the number of remaining teeth and the occlusal relationship.[3–6] However, the causal relationship between these factors is not yet fully understood, and it is assumed that the connection lies between the proprioception of muscle spindles (e.g. the periodontal membrane or the masseter muscle).[7] Some researchers have examined the relationship between body posture and the mandibular position by using a stabilometer in young subjects, and they concluded that the foot center of pressure is not influenced by asymmetric malocclusion or by different dental positions.[8–10] This may indicate a need to focus on the effects of extreme mandibular positions in the elderly population to reveal this relationship.

If the proprioception of the periodontal membrane and muscle spindle affect the one-leg standing time with eyes open, a difference between one-leg standing times with the mouth opened and mouth closed would be expected. Therefore, to determine whether such a difference existed, the authors measured and compared the one-leg standing times with the eyes open and the mouth opened and mouth closed in community-dwelling elderly people.

Correspondence to: Mitsuyoshi Yoshida, Dental Department, Hiroshima City Rehabilitation Hospital, 1-39-1, Tomo-minami, Asaminami-ku, Hiroshima, 731-3168, Japan. E-mail: mitsu@hiroshima-u.ac.jp

DOI 10.1179/2151090314Y.0000000007

Table 1 Comparison between the sexes in age, grip strength, body mass index, number of remaining teeth, and normal one-leg standing time with eyes open (mouth closed)

	Sexes		
Physical Indices	Male	Female	*P*
Age (years)	75.9±5.1	75.4±5.1	0.650^{NS}
Hand grip strength (kg)	33.0±6.5	19.5±4.5	0.000*
BMI (kg/m^2)	24.4±2.5	24.6±3.2	0.903^{NS}
Number of remaining teeth	22.4±8.0	19.0±9.6	0.932^{NS}
Normal one-leg standing time (seconds)	25.3±22.3	25.0±21.2	0.071^{NS}

Note: BMI=body mass index; NS=no significant difference.
*P<0.05, based on the Mann–Whitney *U* test.

Methods

Healthy elderly residents (32 men and 75 women) aged 65–89 years (average age, 75.6±5.1 years) from the Yahatahigashi Ward of Kitakyushu City, Japan were selected for the study. All participants came to the research area (i.e. a community center) voluntarily. Brief medical interviews were performed. Patients with bone and joint disease, neuromuscular diseases, or temporomandibular disorders were excluded as subjects. The study was approved by the Saiseikai Yahata General Hospital Ethics Committee and was conducted with assistance from the Saiseikai Yahata General Hospital in Kokura, Japan.

The authors measured physical indices such as height, weight, and grip strength in the dominant hand and the one-leg standing times with the eyes open. Body mass index (BMI) was calculated by weight/height^2. For the one-leg standing time with eyes open, the authors measured the length of time with the mouth closed (i.e. 'normal') and with the mouth wide open—each for a maximum of 60 seconds. The authors randomized the order of measurements (i.e. open versus close) and waited a minimum of 1 minute between measurements. A dentist confirmed the number of remaining teeth through an intraoral examination: wisdom teeth were included in the measurement, but roots were excluded.

The statistical software PASWver.18 (IBM, Tokyo, Japan) was used for the analysis. These physical indices were compared by nonparametric analysis because one-leg standing times were counted up to 60 seconds. Spearman's rank correlation coefficient was assessed between the normal one-leg standing times and the age, grip strength, BMI and number of remaining teeth. Using the Wilcoxon signed-rank test, one-leg standing times with the mouth closed were compared to one-leg standing times with the mouth opened. Furthermore, subjects were divided into two subgroups: (1) patients whose one-leg standing times were equal or shorter with the mouth opened than with the mouth closed and (2) patients whose one-leg standing times were prolonged with the mouth opened. Physical indices of these subgroups were compared using the Mann–Whitney *U* test. The significance level was set at 0.05.

Results

The mean number of remaining teeth was 20.1±9.2. Everyone who had lost molar teeth contacts on both sides was wearing removable dentures. There was no difference between the sexes for all physical indices examined, except for grip strength (Table 1). Therefore, all variables were compared between both sexes. A significant correlation was observed between normal one-leg standing time with eyes open and age, handgrip strength, BMI, and the number of remaining teeth (Table 2).

The average one-leg standing times with the mouth closed and with the mouth opened were 24.84±21.33 and 21.55±19.24 seconds, respectively. The time was significantly shorter with the mouth opened than with the mouth closed. The shortened group patients, whose standing time was equal or shortened with the mouth opened than with the mouth closed, consisted of 19 males and 46 females. The prolonged group patients, whose time with the mouth opened was prolonged, consisted of 13 males and 29 females. There were no significant differences between the two

Table 2 Comparison between the normal one-leg standing time with eyes open (mouth closed) and the age, grip strength, BMI, and number of remaining teeth

		Age	Grip strength	Body mass index	Number of remaining teeth
Normal one-leg standing time	Correlation coefficient	−0.376	0.193	−0.194	0.316
	P	0.000*	0.047*	0.045*	0.001*

Note: *P<0.05, based on Spearman's rank correlation coefficient.

subgroups in age, handgrip strength, BMI, or the number of remaining teeth (Table 3).

Discussion

The results of the current study confirmed previous findings that a significant correlation exists between the one-leg standing time with eyes open and the number of remaining teeth. Furthermore, the authors found that the one-leg standing time was significantly shorter with the mouth opened than with the mouth closed. It may be concluded that the vertical mandibular position affects the one-leg standing time.

Gangloff and Perrin[11] report that body swaying increases when conduction anesthesia is performed on the mandibular foramen in young, healthy subjects, and they also indicate that the center of gravity changes, depending on experimentally conferred mandibular positions.[12] Both studies support the possibility that the periodontal membrane functions as a proprioceptor that governs body balance.

On the other hand, Perinetti *et al.*[13] found no evidence of changes to the center of gravity in patients with malocclusion, and concluded that postural control is not different in the closed-mouth state, which includes mandibular rest and the intercuspidation positions.[14]

Based on the authors' hypothesis that muscle spindles are more important than the periodontal membrane for postural control, the one-leg standing times with the mouth opened and with the mouth closed were compared. Bracco *et al.*[15] report that the myocentric position determined by muscle contractions lead to smaller differences in the center of gravity, compared to the rest position of the mandibular joints and centric occlusion. In addition, Sforza *et al.*[16] found that changes to the center of gravity can be stabilized with equivalent muscular activity from the right and left masseter muscles during sprinting. Previous studies by the authors indicate that edentulous patients with an unstable lower jaw are more prone to shifts of their centers of gravity and that the number of falls can be reduced in patients with dementia who wear dentures.[4,17] These observations suggest that mandibular stability is important for postural control, and the results of the current study support this conclusion.

However, many methods are available for measuring the one-leg standing time, and researchers select the method.[18] It remains to be seen whether the methods used in this study (e.g. one measurement lasting up to 60 seconds) were appropriate. To gain further insights into the role of the mandibular position on postural control, the authors believe that a more detailed investigation employing a stabilometer will be necessary.

Table 3 Comparison between the 'shortened' and 'prolonged' subgroups

Physical indices	Subgroup: Shortened	Subgroup: Prolonged	*P*
Age (years)	75.5±5.4	75.7±4.5	0.896[NS]
Hand grip strength (kg)	23.5±8.6	23.6±7.2	0.592[NS]
BMI	24.2±2.9	25.1±3.1	0.237[NS]
Number of remaining teeth	20.9±8.9	18.6±9.6	0.266[NS]

Note: NS=No significant differences (at P=0.05, based on the Mann–Whitney U test).
In the 'shortened' group patients, the one-leg standing time was equal or shortened with the mouth open than with the mouth closed. In the 'prolonged' group patients, the one-leg standing time was prolonged with the mouth open.

Conclusion

In this study, the authors found that the one-leg standing time with the mouth opened was significantly shorter than the time with the mouth closed. This may be because the proprioception of the periodontal membrane and muscle spindles becomes functional in the mouth-closed condition. The authors conclude that the vertical mandibular position may affect body posture.

Disclaimer Statements

Contributors Mitsuyoshi Yoshida has contributed in conceiving and designing the study, and writing the article in whole; Yayoi Kanehisa has contributed in collecting the data; Yoshie Ozaki has contributed in collecting the data and obtaining ethics approval; Yasuyuki Iwasa has contributed in collecting the data and analysing the data; Takaki Fukuizumi has contributed in collecting the data and revising the article; Takeshi Kikutani has contributed in obtaining funding.

Funding This study was supported by a Research Grant for Health Promotion of healthcare programs for the elderly from of the Ministry of Health, Labour and Welfare, Japan.

Conflicts of interest There were no conflicts of interest.

Ethics approval The study was approved by the Saiseikai Yahata General Hospital Ethics Committee and was conducted with assistance from the Saiseikai Yahata General Hospital.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Prognosis-related factors concerning oral and general conditions for homebound older adults in Japan

Ryo Suzuki,[1,2] Takeshi Kikutani,[2,3] Mitsuyoshi Yoshida,[4] Yoshihisa Yamashita[5] and Yoji Hirayama[1,6]

[1]Department of General Medicine and Primary Care, Tokyo Medical University Hospital, [2]Division of Rehabilitation for Speech and Swallowing Disorders, Nippon Dental University Tama Oral Rehabilitation Clinic, [3]Division of Clinical Oral Rehabilitation, The Nippon Dental University Graduate School of Life Dentistry at Tokyo, [4]Dental Department, Hiroshima City Rehabilitation Hospital, Hiroshima, [5]Section of Preventive and Public Health Dentistry, Division of Oral Health, Growth and Development, Faculty of Dental Science, Kyushu University, Fukuoka, and [6]Department of General Medicine, Tokyo Medical University, Tokyo, Japan

Purpose: The present study examined the relationship between oral function, such as eating/swallowing, and life prognosis among a homebound elderly population, considering physical and mental function.

Methods: The participants were 511 homebound older adults aged 65 years or older living in four Japanese prefectures. Sex, age, activities of daily living (ADL), cognitive function, underlying disease, nutritional status as Mini-Nutritional Assessment-Short Form (MNA®-SF), swallowing function, dietary modification and occlusal status were examined at baseline. Participants were categorized into poor outcome (died or admitted to hospital or nursing home) and good outcome (still under home care) groups at 1-year follow up, and significant related baseline factors were analyzed. In addition, these groups were compared by the ADL subgroup divided into <60 (lower) and ≥60 (higher) by Barthel Index.

Results: In total, 473 participants were followed up (poor outcome group 177 [37.4%], good outcome group 296 [62.6%]). Sex, age, ADL, MNA®-SF, swallowing function, dietary modification and occlusal support were significantly different between these groups. Logistic regression analysis showed that sex and MNA®-SF score were significantly related to prognosis in the lower ADL group, and sex, age, Charlson Comorbidity Index and occlusal support were significantly related in the higher ADL group.

Conclusions: ADL was strongly correlated with life prognosis in homebound older adults. Within the higher ADL participants, occlusal support was related to this outcome. **Geriatr Gerontol Int 2014; ••: ••–••.**

Keywords: activities of daily living, elderly, nutrition, occlusion, prognosis.

Introduction

Among the elderly population, malnutrition induces decreased immune competence[1] and sarcopenia.[2] As decreased immune competence increases the risk of infections and sarcopenia impairs physical function, malnutrition is important as a factor causing health disorders in these older people. It was reported that more than half of Japanese older adults requiring home care were malnourished or at risk of malnutrition.[3] Malnutrition occurred under these conditions as: (i) chronic diseases, such as cancer, chronic cardiac failure, chronic renal failure and chronic obstructive pulmonary disease; (ii) acute diseases or wounds, such as surgery, acute infection and multiple trauma; and (iii) starvation as a result of insufficient ingestion of energy and protein.[4] Among these, the risk of malnutrition as a result of (iii) is high in older adults, as dietary intake decreases with aging.[5] The risk of malnutrition becomes higher when older adults require long-term care, because these factors are combined with difficulty in oral ingestion as a result of impaired eating/swallowing functions.[6]

It has been reported that malnutrition is directly linked to longevity;[7,8] however, it has not been shown that impaired eating/swallowing function that causes malnutrition[9] is related to life expectancy. The aim of

Accepted for publication 3 August 2014.

Correspondence: Professor Takeshi Kikutani DDS PhD, Division of Rehabilitation for Speech and Swallowing Disorders, Nippon Dental University Tama Oral Rehabilitation Clinic, 4-44-19 Higashi-cho, Koganei-city, Tokyo 184-0011, Japan. Email: kikutani@tky.ndu.ac.jp

the present study was to clarify the relationship between oral function, such as eating/swallowing, and life prognosis among a homebound elderly population, considering physical and mental function.

Methods

We examined 716 homebound older adults aged 65 years or older living in four prefectures of Japan (Tokyo, Kanagawa, Niigata and Fukuoka) from October to December in 2010.[10] Among these participants, 511 participants were followed up 1 year later (162 men, 349 women, mean age 84.2 ± 7.6 years). This study was approved by the ethics committee of Nippon Dental University. All the patients and/or their families gave written informed consent before study participation.

At baseline, sex, age, basic activities of daily living (ADL), cognitive function, underlying disease, nutritional status, swallowing function, dietary modification and occlusal status were examined. The present living status was determined at 1-year follow up by interviewing care managers and physicians of the participants.

ADL

ADL was evaluated using the Barthel Index, which is a widely used index.[11] The participants with a Barthel Index score of ≥60 points (those whose basic actions in daily life were almost independent[12]) were classified as the higher ADL group, and participants with a Barthel Index score of <60 points were classified as the lower ADL group.

Cognitive function

Cognitive function was evaluated using Washington University Clinical Dementia Rating (CDR), an observational method that is widely used to evaluate the severity of dementia throughout the world.[13] Participants with a score of zero and 0.5 were classified as "absence of dementia", and participants with a score of ≥1 were classified as "presence of dementia".

Underlying disease

The underlying disease in each participant was obtained based on the diagnosis of the physician in charge and evaluated using the Charlson Comorbidity Index (concomitant underlying disease index), a concomitant disease index for prognostic evaluation.[14]

Nutritional status

The nutritional status was evaluated using Mini-Nutritional Assessment-Short Form (MNA®-SF) consisting of six screening items in the first step of MNA®, a simple evaluation method for older adults.[15]

Swallowing function

Swallowing function was evaluated according to the neck auscultation method by Zenner *et al.*[16] Each participant was made to ingest 3 mL of water from a glass and the swallowing status was evaluated by neck auscultation.[17] At this time, when a symptom such as choking, respiratory distress or wheezing occurred or the water was swallowed in multiple portions, "presence of swallowing disorder" was judged, and otherwise "absence of swallowing disorder" was judged. The dentist in charge of the test was instructed about the neck auscultation method in advance of the test.

Dietary modification

The interview showed whether the dietary modification, such as puree and nectar, was used or not in the every day diet. Drinking thickened water was also included in the dietary modification.

Occlusal status

A dentist carried out an oral examination at home, and depending on the occlusion status in the molar region, the participants were classified as follows. Participants with occlusion of the molar region with natural teeth or denture(s) at one or more sites were classified as "presence of occlusal support", whereas those with no molar region occlusion with either natural teeth or denture(s) were classified as "absence of occlusal support".

Statistical analysis

According to the follow-up examination, the participants were classified into two groups: (i) participants still receiving home care in the same manner as 1 year ago; and (ii) participants who were admitted to hospital or a nursing home, or died during the last 1-year period. Participants in group (i) were handled as the "good outcome group", and participants in group (ii) were handled as the "poor outcome group." These two groups were compared by the χ^2-test and Mann–Whitney *U*-test. Furthermore, multicollinearity was investigated with Spearman's rank correlation coefficient and Cramer's coefficient of association (Cramer's V). In addition, the participants were divided by Barthel Index score, and the influence of each factor ($P < 0.10$) was investigated by logistic regression analysis in each ADL subgroup. In statistical analysis, PASW Statistics 18 (IBM, Tokyo, Japan) was used, and the level of statistical significance was set at 95%.

Results

Excluding 38 participants (7.4%) in whom the follow-up investigation was not possible as the nursing-care service provided had changed or consent was not obtained, 473 participants (145 men, 328 women, mean age 84.1 ± 7.6 years) were followed up. The good outcome group consisted of 296 participants (75 men, 221 women, mean age 83.5 ± 7.7 years). The poor outcome group consisted of 177 participants (70 men, 107 women, mean age 85.1 ± 7.4 years). Among the poor outcome group, 119 participants (25.2%) were admitted to a hospital or nursing home. The reason for this admission was orthopedic disease in 19, pneumonia in 18, cerebrovascular disease in six, malignant neoplasm in five, cardiac disease in five, other in 30 and unclear in 36. Deceased participants accounted for 58 (12.3%), and the cause of death was pneumonia in 12, senile deterioration in 12, cardiac disease in eight, malignant neoplasm in seven, cerebrovascular disease in three, other in 10 and unclear in six.

The items that showed a significant difference between the good outcome group and poor outcome group were sex, age, ADL, MNA®-SF, swallowing function, dietary modification and occlusal support (Table 1).

Looking at the inter-item correlation, a strong correlation ($P < 0.001$) was detected between Barthel Index and other items, as shown in Table 2. Then, the participants were divided into the following two ADL subgroups for analysis. The lower ADL group with a Barthel Index score of <60 points consisted of 211 participants (67 men, 144 women, mean age 84.5 ± 8.0 years), and the higher ADL group with a Barthel Index score of ≥60 points consisted of 262 participants (78 men, 184 women, mean age 83.8 ± 7.3 years).

Comparing the good outcome group and poor outcome group in each ADL subgroup, a significant difference was recognized for MNA®-SF in the lower ADL group, and for sex, age, Charlson Comorbidity Index, swallowing function and occlusal support in the higher ADL group (Table 3). In addition, the stepwise logistic regression analysis showed that sex and MNA®-SF were identified as prognostic factors ($P < 0.05$) in the lower ADL group, and sex, age, Charlson Comorbidity Index and occlusal support were identified as prognostic factors ($P < 0.05$) in the higher ADL group (Table 4).

Table 1 Comparison between good outcome group and poor outcome group

	Prognosis Good outcome group (*n* = 296)	Poor outcome group (*n* = 177)	Odds ratio (95% CI)	*P*-value
Men, *n* (%)	75 (25.3)	70 (39.5)	0.519 (0.348–0.773)	0.001
Age, mean (SD)†	83.5 (7.7)	85.1 (7.4)		0.034
ADL (Barthel Index), mean (SD)†	64.2 (26.7)	51.1 (29.0)		<0.001
CDR not less than 1, *n* (%)	157 (53.0)	105 (59.3)	1.291 (0.886–1.882)	0.184
Charlson Comorbidity Index, mean (SD)†	1.3 (1.2)	1.6 (1.4)		0.052
MNA®-SF, mean (SD)†	10.4 (2.3)	9.5 (2.3)		<0.001
Presence of swallowing disorder, *n* (%)	73 (24.7)	73 (41.2)	2.144 (1.438–3.196)	<0.001
Dietary modification, *n* (%)	70 (23.6)	69 (39.0)	2.063 (1.377–3.089)	<0.001
Absence of occlusal support, *n* (%)	26 (8.8)	31 (17.5)	2.205 (1.261–3.855)	0.005

†Mann–Whitney *U*-test, others: χ^2 test. ADL, activities of daily living; CDR, Clinical Dementia Rating; CI, confidence interval; MNA®-SF, Mini-Nutritional Assessment-Short Form.

Table 2 Correlation between activities of daily living (Barthel Index) and each examination item

	Sex	Age	CDR	Charlson Comorbidity Index	MNA®-SF	Swallowing disorder	Dietary modification	Occlusal support
Correlation coefficient	0.233†	−0.069	−0.205	−0.194	0.519	−0.261	−0.489	−0.116
P-value	0.178	0.134	<0.001	<0.001	<0.001	<0.001	<0.001	0.011

†Cramer's coefficient of association (Cramer's V). ADL, activities of daily living; CDR, Clinical Dementia Rating; MNA®-SF, Mini-Nutritional Assessment-Short Form.

Table 3 Comparison between good outcome group and poor outcome group in lower and higher activities of daily living group

	Lower ADL group				Higher ADL group			
	Outcome		Odds ratio	*P*-value	Outcome		Odds ratio	*P*-value
	Good outcome group (n = 109)	Poor outcome group (n = 102)	(95% CI)		Good outcome group (n = 187)	Poor outcome group (n = 75)	(95% CI)	
Men, n (%)	28 (25.7)	39 (38.2)	0.558 (0.311–1.004)	0.050	47 (25.1)	31 (41.3)	0.476 (0.271–0.839)	0.010
Age, mean (SD)†	84.2 (8.4)	84.8 (7.5)		0.714	83.1 (7.2)	85.5 (7.2)		0.008
CDR not less than 1, n (%)	66 (60.6)	71 (69.6)	1.492 (0.843–2.640)	0.168	91 (48.7)	34 (45.3)	0.875 (0.511–1.497)	0.626
Charlson Comorbidity Index, mean (SD)†	1.7 (1.5)	1.6 (1.4)		0.992	1.2 (1.0)	1.6 (1.4)		0.040
MNA®-SF, mean (SD)†	9.3 (2.2)	8.6 (2.2)		0.013	11.1 (2.1)	10.8 (1.8)		0.128
Swallowing disorder, n (%)	41 (37.6)	49 (48.0)	1.533 (0.886–2.654)	0.126	32 (17.1)	24 (32.0)	2.279 (1.230–4.223)	0.008
Dietary modification, n (%)	49 (45.0)	57 (55.9)	1.551 (0.901–2.670)	0.113	21 (11.2)	12 (16.0)	1.506 (0.700–3.240)	0.293
Absence of occlusal support, n (%)	13 (11.9)	19 (18.6)	1.690 (0.787–3.630)	0.175	13 (7.0)	12 (16.0)	2.549 (1.105–5.881)	0.024

†Mann–Whitney *U*-test, others: χ^2-test. ADL, activities of daily living; CDR, Clinical Dementia Rating; CI, confidence of interval; MNA®-SF, Mini-Nutritional Assessment-Short Form.

Table 4 Results of stepwise logistic regression analysis in lower and higher activities of daily living group

	B	Standard deviation	Wald test	*P*-value	Exp (B)	95% CI
Lower ADL group						
Sex	−0.657	0.307	4.588	0.032	0.518	0.284–0.946
MNA®-SF	−0.174	0.067	6.875	0.009	0.840	0.737–0.957
Constant	2.605	0.849	9.429	0.002	13.537	
Higher ADL group						
Sex	−0.896	0.326	7.534	0.006	0.408	0.215–0.774
Age	0.085	0.023	13.356	0.000	1.089	1.040–1.140
Charlson Comorbidity Index	0.417	0.142	8.631	0.003	1.518	1.149–2.004
Occlusal support	1.039	0.453	5.254	0.022	2.826	1.163–6.870
Constant	−8.306	2.076	16.012	0.000	0.000	

ADL, activities of daily living; B, partial regression coefficient; Exp (B), exponential function (partial regression coefficient); MNA®-SF, Mini-Nutritional Assessment-Short Form.

Discussion

The results of the present study suggested that occlusal support could be related to life prognosis in homebound older adults whose ADL is relatively maintained.

Regarding the correlation between nutritional status and outcome, low body mass index and hypoalbuminemia were handled as poor-prognostic factors in homebound older adults.[18] In addition, Tsai *et al.* reported that MNA® is a factor capable of predicting the nutritional status and outcome in older adults admitted to a nursing home.[19]

The Barthel Index is a globally used tool for ADL evaluation, and it was reported that the level of independence is high with a Barthel Index score of ≥60 points, severe disability is seen with a score of <40 points and total aid is necessary with a score of <20 points.[12] In the present study, a strong correlation was recognized between ADL and other examination items. Then, in order to avoid multicollinearity, the participants were divided into lower ADL group with a Barthel Index score of <60 points and higher ADL group with a Barthel Index score of ≥60 points for statistical analysis. As a result, in the lower ADL group, a significant correlation was recognized between malnutrition risk and life prognosis, the same as in previous studies.[18,19]

In contrast, in the higher ADL group, nutritional status was not related to life expectancy. In the higher ADL group, the items that showed a significant correlation with life prognosis were underlying disease and occlusal support, as well as sex and age. It could indicate that someone who has maintained relatively high ADL is admitted into the hospital or nursing home suddenly because of deterioration of their underlying medical problems. Furthermore, a significant correlation was recognized between occlusal support and prognosis, so we speculate that loss of occlusal support resulted in a chewing disorder and caused an eating disorder leading to malnutrition.

Many studies have shown that teeth, occlusal support and chewing ability were correlated with nutritional status in older adults, and it is concluded that the presence of occlusal support and chewing ability are favorable factors for nutritional status.[20–22] Chewing ability was produced by occlusal support as well as oral function including tongue, cheek and lips movement,[23] and oral function was significantly related to ADL.[24] It could be quite reasonable in the lower ADL group that oral function had already decreased in the same manner as general physical function, and eating/swallowing disorder and malnutrition were caused by the chewing disorder. In contrast, oral movement for chewing could be maintained in the higher ADL group, so that the existence of occlusal support might be directly involved in maintenance of chewing and eating function.

In the present study, the reason for admission to hospital or a nursing home did not focus on the underlying disease status, so further studies will be required to show that occlusal support is related to life prognosis in homebound older adults whose ADL is relatively maintained. Furthermore, as malnutrition accompanying loss of occlusal support was the cause of sudden worsening of outcome among the relatively ADL maintained group, we should investigate the possibility that recovery of chewing function by restoring occlusal support with denture(s) might improve eating function, leading to improvement of nutritional status and further to improvement of life expectancy.

Acknowledgments

This study was supported by the Ministry of Health, Labor and Welfare. The authors are grateful to all the

participants, care managers, physicians and dentists who participated in this study.

Disclosure statement

The authors declare no conflict of interest.

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Geriatr Gerontol Int 2014

ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Relationship between oral bacteria count and pneumonia onset in elderly nursing home residents

Takeshi Kikutani,[1,2] Fumiyo Tamura,[1] Haruki Tashiro,[2] Mitsuyoshi Yoshida,[3] Kiyoshi Konishi[4] and Ryo Hamada[5]

[1]*Division of Clinical Oral Rehabilitation, The Nippon Dental University Graduate School of Life Dentistry at Tokyo,* [4]*Department of Microbiology, The Nippon Dental University School of Life Dentistry at Tokyo,* [2]*Division of Rehabilitation for Speech and Swallowing Disorders, Nippon Dental University Tama Oral Rehabilitation Clinic,* [3]*Dental Department, Hiroshima City General Rehabilitation Center, Hiroshima, and* [5]*Incubation Center Panasonic Healthcare Co., Ltd., Tokyo, Japan*

Aim: Oral bacteria, which are a source of infection for aspiration pneumonia, were examined in frail older adults with the aim of establishing a standard bacteria count that indicates the risk of pneumonia onset in this group.

Methods: A survey of bacteria count in the saliva using a simple instrument for measurement of the number of oral bacteria, along with factors including swallowing function and nutritional status, was carried out in 691 elderly individuals requiring care (137 men; mean age 82.6 ± 8.3 years; 554 women; mean age 88.0 ± 7.1 years; total mean age 86.7 ± 7.8 years) at 16 nursing homes in Japan. All participants gave their consent for inclusion in the present study. During a 6-month follow-up period, participants who developed pneumonia were identified, and relationships between the factors measured at the start of the period and pneumonia onset were examined.

Results: During the 6-month follow-up period, 33 participants (4.8%; 5 men, 28 women; mean age 88.3 ± 7.4 years) developed pneumonia. Pneumonia onset was significantly associated with reduced activities of daily living, swallowing dysfunction and undernourishment. Logistic regression analysis identified a saliva bacteria count of $10^{8.5}$ colony-forming units/mL as an independent explanatory factor for pneumonia onset ($P = 0.012$, $RR = 3.759$).

Conclusions: Oral bacteria count of $10^{8.5}$ colony-forming units/mL saliva in an elderly person requiring care was identified as a risk factor for pneumonia onset. **Geriatr Gerontol Int 2014; ••: ••–••.**

Keywords: aspiration pneumonia, oral bacteria count, oral health care.

Introduction

Older adults are known to have a high incidence of aspiration pneumonia, and this is believed to be associated with intraoral bacteria infection.[1] Many bacteria that are specific causative agents of pneumonia are present in the oral cavity,[2] and it is difficult to selectively reduce the number of pneumonia-causing bacteria. Oral care can lead to favorable changes in the composition and abundance of oral bacteria,[3,4] and it has been reported that specialist oral care can reduce the number of days of fever and the frequency of pneumonia onset,[5,6] as well as reduce the mortality rate from pneumonia.[7]

Terpenning *et al.* discussed the economic effectiveness of carrying out oral care in these cases, and also calculated the cost of oral care in terms of human resources.[8] They found that oral care is highly effective. We determined the oral bacteria count in older adults requiring care using a simple instrument recently developed for the measurement of the number of oral bacteria,[9,10] and investigated the relationship between the oral bacteria count and subsequent pneumonia onset. We then used these findings to identify individuals at high risk of pneumonia onset. We expect that this type of screening program will enable the implementation of intensive oral care for high-risk individuals and will contribute to the prevention of aspiration pneumonia onset, which is significant from the perspective of medical economics.

Accepted for publication 17 February 2014.

Correspondence: Professor Takeshi Kikutani DDS PhD, Division of Rehabilitation for Speech and Swallowing Disorders, Nippon Dental University Tama Oral Rehabilitation Clinic, 4-44-19 Higashi, Koganei-shi, Tokyo 184-0011, Japan. Email: kikutani@tky.ndu.ac.jp

doi: 10.1111/ggi.12286

The present study focused on the number of oral bacteria, which are a source of infection in aspiration pneumonia, with the aim of establishing a standard oral bacteria count for assessing the risk of pneumonia onset.

Methods

Participants

The survey was carried out in 691 older adults requiring care (137 men; mean age 82.6 ± 8.3 years; 554 women; mean age 88.0 ± 7.1 years; total mean age 86.7 ± 7.8 years) at 16 nursing homes in Japan who gave their consent to participate in the present study. We explained the purpose and procedure of the study to the participants both orally and in writing, and we obtained written informed consent from all participants or their families. The study was approved by the ethics committee of The Nippon Dental University, School of Life Dentistry at Tokyo.

Bacteria count

Oral bacteria count was determined using saliva collected from the sublingual area within 30 min of waking. To obtain a specimen, we rinsed a cotton swab in saliva in the floor of the oral cavity for 10 s. Participants were not permitted to eat or drink between waking and saliva collection. Bacteria were enumerated using a simple instrument for the measurement of the number of oral bacteria developed by Hamada *et al.*[9] and Kikutani *et al.*,[10] and counts were stratified into the following categories (colony-forming units [CFU]/mL): $<10^{6.5}$; $\geq 10^{6.5}$ to $<10^{7}$; $\geq 10^{7}$ to $<10^{7.5}$; $\geq 10^{7.5}$ to $<10^{8}$; $\geq 10^{8}$ to $<10^{8.5}$; $\geq 10^{8.5}$ to $<10^{9}$; and $\geq 10^{9}$.

Comorbidities

Comorbidities in participants were determined from medical records.

Swallowing disorders

Swallowing disorders were defined as being present in cases where choking or accidental aspiration were present, as well as in cases exhibiting a gargling sound on auscultation of the neck region[11] after swallowing 3 mL of water.

Nutritional status

Nutritional status of participants was determined by calculating body mass index (BMI) from height and weight. BMI < 18.5 was considered to show undernourishment.

Xerostomia

The presence or absence of xerostomia was assessed according to the following categories reported by Kakinoki *et al.*: dry, mildly dry, wet (normal) and wet (high).[12] Dry and mildly dry categories indicate the presence of xerostomia.

Activities of daily living

Evaluation of activities of daily living was carried out using the Barthel Index 1.[13]

Survey of aspiration pneumonia

The follow-up period was 6 months, and onset of aspiration pneumonia during this period was assessed. Pneumonia was diagnosed by each participant's primary physician. Criteria for diagnosis of pneumonia were a new pulmonary infiltrate seen on a chest radiograph and one of the following features: cough, temperature greater than 37.5°C or subjective dyspnea.

Statistical analysis

The χ^2-test was used to assess the relationship between pneumonia onset and various factors, and to test the cut-off point for bacteria count with respect to pneumonia onset. In addition, onset and bacteria count were analyzed using multiple logistic regression analysis to identify statistically significant levels.

Statistical analysis was carried out using PASW Statistics 18 (IBM, Tokyo, Japan) with a 95% significance level.

Results

Onset of pneumonia

A total of 33 participants (4.8%; 5 men, 28 women; mean age 88.3 ± 7.4 years) developed pneumonia during the 6-month follow-up period. No differences in distribution as a result of sex or age were observed. The Barthel Index was significantly lower among participants who developed pneumonia (pneumonia group; 14.71 ± 24.65) than among those of who did not (non-pneumonia group; 33.46 ± 27.95; $P = 0.007$). The proportion of participants with malnourishment was greater in the pneumonia group (40.7%) than in the non-pneumonia group (31.4%; $P = 0.2$). Dysphagia was also significantly more common in the pneumonia group (56.3%) than in the non-pneumonia group (39.0%; $P = 0.04$). No significant differences were found between the two groups with respect to the incidence of comorbidities, with the exception of heart disease and dementia (Table 1).

Table 1 Pneumonia onset and baseline characteristics

	Pneumonia (+)	Pneumonia (–)	*P*-value
Total % of men	15.0	20.4	0.40
Age (years)	88.36 ± 7.47	86.63 ± 7.81	0.31
Barthel Index score	14.71 ± 24.65	33.46 ± 27.95	0.007
Nutritional status (% malnourished)	40.7	31.4	0.20
Presence of swallowing disorder (%)	56.3	39	0.04
Presence of xerostomia (%)	43.8	34.7	0.193
Presence of cerebrovascular disease (%)	39.3	47.9	0.242
Presence of ischemic heart disease (%)	42.9	22.3	0.02
Presence of hypertension (%)	46.4	38.9	0.271
Presence of diabetes mellitus (%)	10.7	15.36	0.353
Presence of dementia (%)	78.6	58.7	0.026

Data are expressed as mean ± standard deviation.

Table 2 Relationship between pneumonia onset and bacteria count

Bacteria count, log (CFU mL-1)	Pneumonia (+)	Pneumonia (–)	Total
<6.5	2	39	41
≥6.5–<7	1	29	30
≥7–<7.5	6	114	120
≥7.5–<8	5	218	223
≥8–<8.5	10	165	175
≥8.5–<9	7	70	77
≥9	2	23	25
Total	33	658	691

CFU, colony-forming unit.

Setting the cut-off point

Table 2 shows the relationship between pneumonia onset and bacteria count category. In order to identify an index for carrying out specialist oral care, the following oral bacteria count cut-off points were considered (CFU/mL): $\geq 10^{7.5}$, 10^{8}, $10^{8.5}$ and 10^{9}. The models with $\geq 10^{8}$ CFU/mL and $\geq 10^{8.5}$ CFU/mL as cut-off points showed significant differences in the incidence of pneumonia ($\geq 10^{8}$ CFU/mL: $RR = 1.052$, 95% CI 0.988–1.120, $P = 0.041$; $\geq 10^{8.5}$ CFU/mL: $RR = 1.037$, 95% CI 1.000–1.076, $P = 0.029$; Table 3).

Logistic regression analysis

A logistic regression model was used to examine whether an established cut-off value for oral bacteria count could be a factor in predicting pneumonia onset. The correlation matrix for the tested factors is shown in Table 4. As the Barthel Index showed a significant correlation with bacteria count, it was excluded from the logistic regression analysis to avoid multicollinearity. Oral bacteria count $\geq 10^{8.5}$ CFU/mL was an independent explanatory factor for pneumonia onset ($P = 0.012$, $RR = 3.759$, 95% CI 1.332–10.611; Table 5).

Discussion

Aspiration pneumonia develops when pathogenic bacteria are drawn from the oral cavity or pharynx into the trachea during respiration.[1] Aspiration of bacteria in oropharyngeal secretions is considered to be a major risk factor for nosocomial pneumonia in older adults;[14,15] therefore, poor oral hygiene is thought to be an important cause of pneumonia. Oral bacteria count can be reduced through specialist oral care.[3,4] In a random intervention study at a nursing home, the incidence of pneumonia was reduced through oral care intervention.[5,7] Abe *et al.* identified a relationship between saliva bacteria count and visual evaluation of tongue coating and dental plaque, as well as a relationship between the results of visual evaluation and pneumonia onset.[16,17] It has been reported that, as a result of the wide varieties of weak pathogenic bacteria that can cause aspiration pneumonia, bacteria count is a more important indicator than bacterial type or species in the prevention of aspiration pneumonia.[18] As bacteria count is likely to be a useful parameter for evaluating the risk of aspiration pneumonia, saliva bacteria count was used as an indicator of the oral environment in the present study.

The mechanism of aspiration pneumonia onset involves not only bacteria as the source of infection, but also includes aspiration as the route of infection and undernourishment as a factor in the status of the infected host.[19] Specifically, swallowing function plays a significant role in the onset of aspiration pneumonia,[20,21] and the need to evaluate swallowing function in the prevention of aspiration pneumonia has often been reported. Teramoto *et al.* described the "swallowing

Table 3 Relationship between pneumonia onset and cut-off point

	Bacteria count (log)	Pneumonia (+)	Pneumonia (–)	*P*-value	RR	Lower	Upper
Model 1	≥7.5	72.7%	72.3%	0.57	1.001	0.964	1.039
Model 2	≥8	57.6%	39.2%	0.029	1.037	1	1.076
Model 3	≥8.5	27.3%	14.1%	0.041	1.052	0.988	1.12
Model 4	≥9	6.1%	3.5%	0.338	1.036	0.922	1.165

RR, relative risk.

Table 4 Correlation matrix for tested factors

		Bacteria count category	Barthel Index	Age	Nutritional status	Swallowing disorder
Bacteria count category	Correlation	1.000	–0.146	–0.019	–0.069	–0.035
	P-value		0.001	0.676	0.093	0.369
Barthel Index	Correlation	–0.146	1.000	–0.125	0.167	–0.360
	P-value	0.001		0.009	0.000	0.000
Age	Correlation	–0.019	–0.125	1.000	0.003	–0.037
	P-value	0.676	0.009		0.948	0.421
Nutritional status	Correlation	–0.069	0.167	0.003	1.000	–0.112
	P-value	0.093	0.000	0.948		0.006
Swallowing disorder	Correlation	–0.035	–0.360	–0.037	–0.112	1.000
	P-value	0.369	0.000	0.421	0.006	

Table 5 Logistic regression analysis of independent predictors for pneumonia onset

	B	SE	*P*-value	Relative risk (95% confidence interval)	
Sex (reference, male)	–0.288	0.672	0.688	0.750	0.201–2.800
Age	–0.020	0.034	0.552	0.980	0.980–1.047
Nutritional status (reference, malnourished)	0.211	0.520	0.685	1.235	0.445–3.424
Swallowing disorder (reference, presence)	–0.362	0.492	0.462	0.696	0.265–1.827
Bacteria count category (reference, <log 8.5)	1.324	0.529	0.012	3.759	1.322–10.611

provocation test" and the "simple swallowing provocation test" as effective methods for testing swallowing function in the prediction of aspiration pneumonia onset.[22] Poor nutritional status is associated with reduced immune function, and has been identified as a cause of various infectious diseases in older adults.[23,24]

Few reports on the relationship between pneumonia onset and oral bacteria have taken swallowing function and nutritional status into account, and these studies were limited to univariate analysis[25] or the addition of variables, such as the presence of periodontal disease or tooth decay and the use of artificial teeth.[19,26] The present study included swallowing function and nutritional status in the evaluation of pneumonia onset risk, and used multivariate analysis to determine a cut-off point at which oral bacteria count alone increases the risk of pneumonia.

A limitation of the present study was the use of a prospective cohort. Future studies should include oral care interventions in older adults with various oral bacteria counts in order to investigate whether reducing the oral bacteria count to a set level is effective in reducing the incidence of pneumonia. We set the observation period for 6 months in the present study. The reason why the follow-up period was 6 months in the present study was that the previous study reported that oral care intervention for approximately 6 months was required for significantly decreasing the number of oropharyngeal bacteria.[27] In this regard, in cases of prolongation of oral care intervention, there is a possibility of producing different results.

In the present study, pneumonia onset was observed for all bacteria count categories, suggesting that controlling oral bacteria might not completely prevent