The Relationship Between Oral Function and Body Mass Index Among Independently Living Older Japanese People

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Purpose: This study aimed to clarify the relationship between oral function and Body Mass Index (BMI) using data from independently living, relatively healthy older people. The hypothesis was that oral function is more important than dental status for healthy body weight. ***Materials and Methods:*** The subjects were community-dwelling, independently living elderly people over 60 years of age (N = 807, 408 men and 399 women). An oral health examination, an oral and general health interview, and measurement of oral function, such as masticatory performance and occlusal force, were carried out. BMI (kg/m^2) was used to measure body fat. A multiple logistic regression analysis was used for 2 outcome variables of underweight and overweight. ***Results:*** Overall, 70.1% of the subjects were in the normal category of BMI (20 to 25), 13.4% were in the underweight category (< 20), and 16.5% were in the overweight category (> 25). Neither occlusal force nor masticatory performance was significantly correlated with BMI. However, when the lowest 20% of occlusal force and masticatory performance values were used as explanatory variables, multiple logistic regression analyses showed that being underweight was significantly associated with having lower masticatory performance (odds ratio = 2.0, P = .015). In addition, being overweight was significantly associated with lower occlusal force (odds ratio = 1.8, P = .013). There was no statistical difference in the underweight or overweight proportions as a function of either number of teeth or type of dentition. ***Conclusion:*** Based on the results of this study, occlusal force and masticatory performance, rather than number of teeth or type of dentition, may play an important role in maintaining a normal BMI in independently living older Japanese people. *Int J Prosthodont 2006;19:539–546.*

Elderly people face significant challenges in achieving an adequate dietary intake, not only because of appetite loss, but also because of alterations in the absorption and metabolism of key nutrients.[1] Low body weight and rapid unintentional weight loss are highly predictive of mortality and morbidity in elderly populations.[2] The factors that contribute to poor nutritional status include alternations in the gastrointestinal tract, functional disabilities, lowered socioeconomic status, social isolation, and chewing problems.

It has been reported that dental status can affect food preference, dietary intake, and nutrition.[3–9] Loss of the natural teeth has been reported as related to being underweight in some studies.[2,10–13] Difficulty in chewing is probably the most likely mechanism by which poor oral health status may affect dietary intake.[4,8,14–18]

In contrast, one study showed that the nutritional intake of elderly patients did not vary significantly among groups with different dentitions.[19] Differences in body weight related to oral health status were not found in several other studies.[20,21] Several studies indicated that prosthesis replacement may improve function but does

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not significantly change dietary intake.[22–26] Thus, there is conflicting evidence regarding whether people with poor oral health status are more likely to be underweight.

Compared to number of remaining teeth or type of dentition, oral function, such as masticatory performance and occlusal force, has received less attention, probably because it is difficult and time consuming to assess. Masticatory performance has been strongly associated with number of remaining teeth.[27–30] However, it is not solely determined by number of remaining teeth, and it varies among patients with the same status because of oral sensory and/or motor function differences, eg, salivary flow and quality of prostheses.[30–32] There are few reports on the relationship between objective oral function and body weight.

This study aimed to clarify the relationship between oral function and Body Mass Index (BMI) using data from independently living, relatively healthy older people. The hypothesis was that oral function is more important than number of remaining teeth for healthy body weight.

Materials and Methods

The subjects were students of the Senior Citizens' College of Osaka prefecture who voluntarily attended the program. The study sample consisted of community-dwelling, independently living people over the age of 60 years who attended lectures once a week. The college is part of an adult education system supported by the government of Osaka prefecture, which enrolls volunteers for a period of 1 year. This course focused not only on health topics but also on other topics of interest to elderly people, such as finances or culture.

At the end of a presentation on oral health issues, the purpose and procedures of this study were explained to the audience, and volunteers were solicited to fill out a questionnaire and return for an oral health examination on another day. After informed consent was obtained, subjects were given the opportunity to ask questions while completing the questionnaires. Subjects could refuse to participate in the oral health examination portion of the study. The study population that voluntarily participated in the dental and oral examination comprised 807 persons (408 men and 399 women). The protocol of this study was approved by the Institutional Review Board of Osaka University Graduate School of Dentistry. All subjects gave written informed consent for their participation.

An oral and general health interview and a measurement of oral function were carried out by 5 calibrated dental clinicians in a classroom of the college. As part of the informed consent, participants were told that their dental needs would not be treated as part of the study, but that they would be referred to their dental practitioner for care, if necessary. In addition, measurements of masticatory performance and occlusal force were obtained. Removable denture wearers kept their dentures in place during the measurements.

To measure body fat, height and weight were used to calculate BMI, a ratio between the weight in kilograms and the height in meters squared (weight [kg]/height^2 [m^2]). A ratio of 20 to 25 was considered normal, while less than 20 was defined as underweight. Values between 25 and 30 were defined as overweight, and values of 30 or over were defined as obese.[33]

Number of Natural Teeth and Type of Dentition

The number of remaining natural teeth was used as an index of oral health status. Types of dentition were classified into 4 groups: *(1)* edentulous (wearing complete dentures in either the maxilla or mandible), *(2)* partially edentulous (wearing at least 1 removable partial denture), *(3)* partially edentulous with no replacement, and *(4)* natural dentition in both the maxilla and the mandible.

Maximal Occlusal Force

Bilateral maximal occlusal force was measured with pressure-sensitive sheets that were 97 μm thick (Dental Prescale 50H R type, Fuji Film).[34–36] The subjects were asked to clench as hard as possible with their teeth in the intercuspal position while a pressure-sensitive sheet was placed between the arches.

Masticatory Performance

Masticatory performance was determined by the concentration of dissolved glucose obtained from the test gummy jellies, which are the standardized food developed for measuring masticatory performance.[37] The subjects were instructed to chew the gummy jelly using 30 chewing strokes on their preferred chewing side (left, right, or both) and then to expectorate the bolus of comminuted particles as thoroughly as possible. The gummy jelly was broken down into particles by mastication. The concentration of dissolved glucose from the chewed gummy jelly was measured with a blood glucose meter (Glutest, Sanwa Chemical Laboratory).[38] The masticatory performance was assessed by calculating the surface area of particles (mm^2) from the glucose concentration, using linear regression.

In a previous study,[38] the concentration of glucose dissolved from comminuted particles of the test gummy jelly indicated high reproducibility when the rinsing

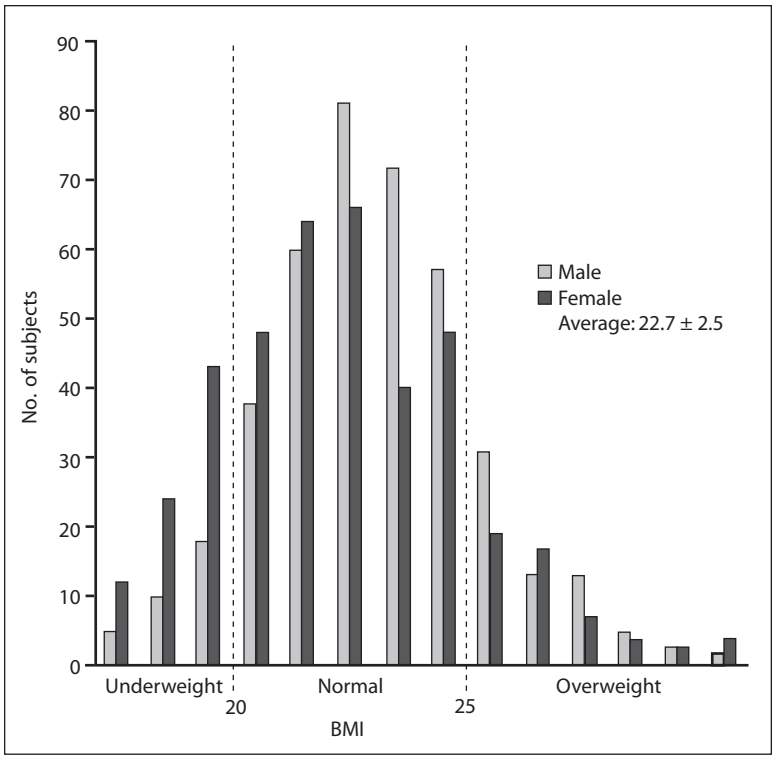

Fig 1 Frequency distribution of BMI.

time, temperature of the distilled water, and dissolution time of the glucose were strictly prescribed. A linear regression analysis showed that the concentration of glucose had a significantly high correlation to the surface area (mm^2) of the comminuted jelly ($r = 0.993$, $P < .01$).

Statistical Analysis

The data analyses included descriptive and analytic statistics and were conducted using SPSS Version 13.0 for Windows (SPSS). $P \leq .05$ was considered statistically significant.

The chi-square test was used to measure the association between various factors and being underweight or overweight. Spearman correlation coefficients were used to evaluate the relationship between occlusal force or masticatory performance and BMI.

Finally, because undernutrition is a multifactorial condition, a multiple logistic regression analysis was used in 2 tests of the explanatory variable's relationship with dichotomous outcome variables after controlling for the other factors. The first outcome was underweight and the second was overweight. All explanatory variables were forced to enter into the model. For this analysis, age was a continuous variable, and gender was dichotomous (men = 0, women = 1). For self-assessed general health, "good" was set to 0 (the reference category), and "fair" and "poor" were set to 1. For number of teeth, 24+ was the reference category. For type of dentition, "natural dentition" was the reference category. For occlusal force and masticatory performance, the 20th percentile and higher was the reference category, and anything else was set to 1.

Results

Complete data were available for 807 people. The frequency distribution of BMI is presented in Fig 1. The average BMI was 22.7 (SD = 2.5). The average for males (22.9, SD = 2.3) was significantly higher than for females (22.5, SD = 2.6).

BMI data were categorized as underweight (< 20), normal (20 to 25), overweight (26 to 30) and obese (> 30).[1] Overall, 70.1% of the subjects were in the normal category, 13.4% were underweight, 15.6% were overweight, and only 7 subjects (0.9%) were in the obese category.

Table 1 shows that women, people with fewer than 10 teeth, and people with complete dentures in at least 1 arch were significantly more likely to be underweight than the other groups. There was no statistically significant difference in the percentage of underweight subjects by age or self-assessed general health.

Overall, neither occlusal force nor masticatory performance was significantly correlated with BMI (Figs 2 and 3). However, when the lowest 20% of occlusal force and masticatory performance values were used as explanatory variables, both were significantly

Table 1 Prevalence of Underweight and Overweight in Different Groups

	n (%)	% underweight	*P**	% overweight	*P**
Total	807 (100.0)	13.4		15.6	
Age					
60–64	316 (39.2)	12.0	.652	16.1	.685
65–69	327 (40.5)	14.1		16.2	
70+	164 (20.3)	14.6		13.4	
Gender					
Male	408 (50.6)	7.6	< .001	16.7	.404
Female	399 (49.4)	19.3		14.5	
Self-assessed general health†					
Good	428 (54.2)	12.0	.487	14.3	.241
Fair	299 (37.9)	14.4		18.1	
Poor	62 (7.9)	16.1		11.3	
No. of teeth					
0–9	69 (8.6)	21.7	.008	13.0	.525
10–19	123 (15.2)	8.1		17.1	
20–23	112 (13.9)	7.1		19.6	
24+	503 (63.3)	14.9		14.7	
Type of dentition†					
Edentulous	75 (9.5)	21.3	.009	16.0	.631
Partially edentulous	282 (35.7)	8.9		14.9	
Partially edentulous with no replacement	29 (3.7)	6.9		24.1	
Natural dentition	404 (51.1)	15.4		15.4	

*Chi-square test.
†Does not equal 807 because of missing values.

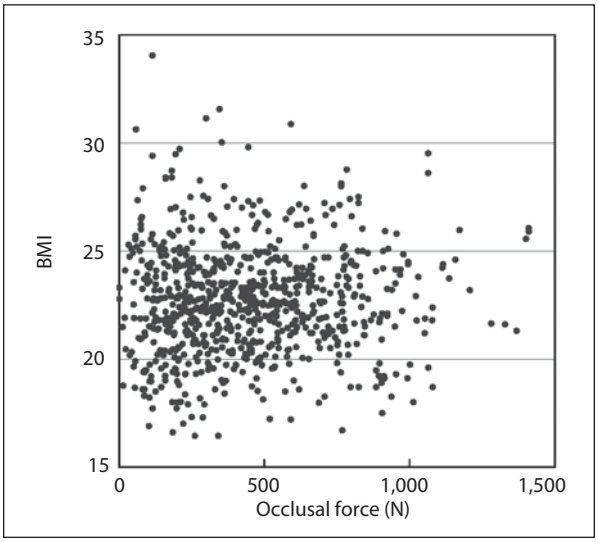

Fig 2 Correlation between occlusal force and BMI.

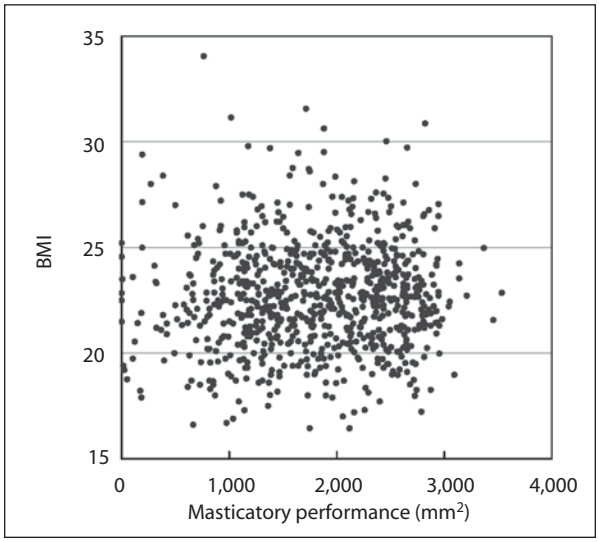

Fig 3 Correlation between masticatory performance and BMI.

associated with being underweight (Table 2). Lower occlusal force was also significantly associated with being overweight.

A multiple logistic regression analysis showed that being underweight was significantly associated with being female and having poorer masticatory performance (Table 3). With regard to the odds ratio, the poorest masticatory performance group was approximately 2 times more likely to be underweight compared to the middle and higher groups (odds ratio = 1.98, P = .015). Occlusal force was likely to be related to being underweight (odds ratio = 1.56, P = .094). In addition, a multiple logistic regression analysis showed that being overweight was significantly associated only with lower occlusal force (odds ratio = 1.82, P = .013) (Table 4). There were no statistical relationships in subjects who were underweight or overweight as a function of either number of teeth or type of dentition.

Table 2 Association of Lower Occlusal Force and Lower Masticatory Performance with Underweight and Overweight

	n (%)	% underweight	*P**	% overweight	*P**
Total	807 (100.0)	13.4		15.6	
Occlusal force (N)†					
Lower (< 200)	166 (20.8)	19.9	.007	21.1	.022
Middle and higher (≥ 200)	633 (79.2)	11.8		13.9	
Masticatory performance (mm^2)					
Lower (< 1,160)	159 (19.7)	20.1	.005	17.6	.439
Middle and higher (≥ 1,160)	648 (80.3)	11.7		15.1	

*Chi-square test.
†Does not equal 807 because of missing values.

Table 3 Logistic Regression Model for Underweight by Forced Enter Method

Explanatory variables	B	SE	*P*	Odds ratio	95% confidence interval
Age*	0.008	0.027	.783	1.01	0.95–1.06
Gender†	1.031	0.239	< .001	2.80	1.76–4.48
Self-assessed general health†			.766		
Good				1	
Fair	0.063	0.232	.785	1.07	0.68–1.68
Poor	0.287	0.395	.468	1.33	0.61–2.89
No. of teeth†			.195		
0–9	−0.238	0.708	.737	0.79	0.20–3.16
10–19	−0.792	0.487	.104	0.45	0.17–1.18
20–23	−0.778	0.461	.092	0.46	0.19–1.13
24+				1	
Type of dentition†			.541		
Edentulous	0.468	0.794	.556	1.60	0.34–7.56
Partially edentulous	0.787	0.784	.315	2.20	0.47–10.21
Partially edentulous with no replacement	0.905	0.987	.359	2.47	0.36–17.10
Natural dentition				1	
Lower occlusal force†	0.442	0.264	.094	1.56	0.93–2.61
Lower masticatory performance†	0.683	0.281	.015	1.98	1.14–3.43

*Continuous variable.
†Categorical variables: Gender: male = 0, female = 1; self-assessed general health: good = 0, other = 1; number of teeth: 24+ = 0, other = 1; type of dentition: natural dentition = 0, other = 1; occlusal force: 20th percentile and higher (≥ 200 N) = 0, lower (< 200 N) = 1; masticatory performance: 20th percentile and higher (≥ 1,160 mm^2) = 0, lower (< 1,160 mm^2) = 1.
B = partial regression coefficient.

Table 4 Logistic Regression Model for Overweight by Forced Enter Method

Explanatory variables	B	SE	*P*	Odds ratio	95% confidence interval
Age*	−0.039	0.027	.146	0.96	0.91–1.01
Gender†	−0.295	0.209	.157	0.74	0.49–1.12
Self-assessed general health†			.159		
Good				1	
Fair	0.288	0.212	.173	1.33	0.88–2.02
Poor	−0.475	0.460	.301	0.62	0.25–1.53
No. of teeth†			.116		
0-9	-0.846	0.692	.212	0.42	0.11–1.64
10-19	0.171	0.396	.667	1.19	0.55–2.58
20-23	0.533	0.333	.109	1.70	0.89–3.27
24+				1	
Type of dentition†			.420		
Edentulous	−0.404	0.489	.409	0.67	0.26–1.74
Partially edentulous	−0.210	0.501	.674	0.81	0.30–2.16
Partially edentulous with no replacement	0.380	0.719	.596	1.46	0.36–5.98
Natural dentition				1	
Lower occlusal force†	0.599	0.241	.013	1.82	1.14–2.92
Lower masticatory performance†	0.179	0.266	.500	1.20	0.71–2.01

*Continuous variable.
†Categorical variables: Gender: male = 0, female = 1; self-assessed general health: good = 0, other = 1; number of teeth: 24+ = 0, other = 1; type of dentition: natural dentition = 0, other = 1; occlusal force: 20th percentile and higher (≥ 200 N) = 0, lower (< 200 N) = 1; masticatory performance: 20th percentile and higher (≥ 1,160 mm^2) = 0, lower (< 1,160 mm^2) = 1.
B = partial regression coefficient.

Discussion

This cross-sectional study evaluated a sample of functionally independent older urban adults who had volunteered for an educational program. How representative these individuals are of elderly Japanese is not precisely known. However, in Japan, most elderly people (95.5% of people 75 to 79 years old) are functionally independent and have no limitations in their daily activities.[39] It is important to know the oral health of such people, who appear to represent a majority of the elderly population. In institutions, a similar diet is generally provided for all residents regardless of eating ability, though it is often tailored to those with the poorest masticatory capacity.[7] Factors that contribute to poor nutritional status include alterations in the gastrointestinal tract, functional disabilities, lowered socioeconomic status, social isolation, and chewing problems.[2] Therefore, to exclude these factors and focus on chewing problems, we used comparatively healthy, cognitively normal, and financially independent subjects for this study.

Generally, BMI is lower and obesity is less prevalent among Japanese than among Westerners.[40] For example, the prevalence of obesity is highest in the United States (30.9%) and the second lowest in Japan (3.6%). This is a result of racial and lifestyle differences.[41,42]

The average BMI in this study (22.9 for men, 22.5 for women) was a little lower than that of the Japanese national survey in same age group (23.6 for both).[43] In the study subjects, the proportion of those with normal weight was 71%, while it was 65% for those in the survey. This means that the prevalence of overweight in this study was lower than that shown in the national survey. This could be attributed to the fact that the study population in this study was not only relatively healthy and intelligent, but able to attend a lecture once a week. Ninety-two percent of the subjects reported that their self-assessed general health was "good" or "fair." These proportions were significantly higher than the nationwide data.[43] Total medical costs were lowest when the BMI ranged from 21 to 23 in Japanese older adults,[44] showing that relatively healthy people have lower body weight.

Socioeconomic status may be an important variable for BMI. But in Japan, asking questions about educational or income level, especially of older people, is considered impolite and may result in a refusal to participate in the study. Therefore, questions were instead asked regarding subjects' satisfaction with their financial status. Responses were gathered from about half of the subjects. Only 6.9% of the subjects reported dissatisfaction with their present financial status, suggesting that they might be a more middle-class group than would be found in the general population. There was no statistically significant difference in BMI when correlated to dissatisfaction with financial status.

Mastication is considered the basis for proper digestion and absorption of nutrients, though there is little supporting evidence. Masticatory performance, which is the ability to break down foods into discrete portions by chewing to permit swallowing, is usually assessed by measuring the size of test-food samples that have been chewed for a specific number of chewing cycles.[1] Fractional sieving has been used since 1950[45] to measure masticatory performance with various natural and artificial foods.[46] However, it has been reported that the masticatory performance values obtained by calculating the area of the gelatin particles achieve better discrimination between subjects.[47] Other advantages of the methodology are the speed and accuracy of measurement. Therefore, gummy jelly was the preferred food for measuring masticatory performance in this study.[34,37]

No significant correlation was found between occlusal force or masticatory performance and BMI, meaning that these relationships were not linear, and higher masticatory ability was not necessarily related to being overweight. This seems reasonable, in that subjects concerned about their oral health and keeping their teeth are probably careful about not becoming overweight. To assume linearity may cancel or mask the true association. Therefore, we analyzed the relationship between poorer masticatory performance or lower occlusal force with cut-off values that defined being underweight or overweight. There is no established cut-off value for the definition of poorer masticatory performance or lower occlusal force in the literature. Thus, in the present study, the 20th percentile was used as the cut-off value.

A review of the data indicates that poor masticatory performance, rather than number of remaining teeth or type of dentition, had a significant relationship with being underweight, once likely confounding effects are taken into account. This suggests that function is more important than morphology. Neither number of teeth nor type of dentition is equal to masticatory function in its effect. A low BMI is easily explainable on the basis of there being real functional difficulties that can prevent normal eating in some cases. Some subjects with relatively poor mastication limited their food selection and hence reduced nutrient intake. On the other hand, better masticatory performance was not likely to be associated with being overweight. Persons taking care of their oral health tend to be concerned about the quality and quantity of their diet and avoid becoming overweight.

It has been reported that the main causes of obesity are excessive food intake (especially saturated fat

intake), lack of regular physical activity, and genetic factors.[48] Interestingly, people with lower occlusal force showed a higher percentage of being overweight. Declining masticatory function can lead individuals to avoid foods considered difficult to chew and to favor soft, easily chewed foods instead.[49–51] Such food selection habits may result in simple carbohydrate–rich diets, which are high in calories but low in dietary fiber, vitamins, and protein,[51–53] thus leading to weight gain.[21]

From the perspective of both public health and individual health care, it is important to understand the relationship between oral health and body weight if they are to be managed appropriately in elderly patients.[33] Most efforts to improve the diets of older people have been directed at health education. Relatively little attention has been paid to the impact of oral health, which can impose dietary restrictions with consequences for nutrition.[54] Health promotion strategies should involve retraining and restoring oral function to avoid harmful dietary restrictions. This is especially important for frail and dependent elderly patients. Diet or nutrition education has focused mainly on avoiding excess weight to prevent cardiovascular disease, diabetes, or other chronic diseases[55] for the middle-aged population. The underweight older population has been largely neglected. After proper evaluation of an individual's masticatory performance, a more varied and nutrient-rich diet should be provided for those who are able to eat it.[7]

It has been reported that masticatory performance is related to intake of dietary fiber,[56] an important component of the diet associated particularly with gastrointestinal health. Future studies are needed to investigate the associations between occlusal force or masticatory performance, the intake of essential foods (eg, fruits and vegetables), and gastrointestinal diseases.

Conclusion

Occlusal force and masticatory performance, rather than number of teeth or type of dentition, may play an important role in maintaining a normal BMI in relatively healthy, independently living older Japanese people.

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