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Original Article

Percentile Curves for Food Acceptance Response Scores in Assessing Chewing Functions in Adults

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Abstract

The purpose of this study was to evaluate whether percentile curves for food acceptance response scores were useful in assessing oral and occlusal conditions. We used data obtained from Chiba City Patient Surveys (males: 1,276, females: 1,381, aged 20 to 64), which were conducted in 1998 and 1999. Subjects were assigned scores of between 1 and 4 for 31 different kinds of food based on their food acceptance responses. Occlusal conditions were measured with pressure-sensitive sheets. We calculated the percentile values from 5 to 95 at intervals of five years. We divided the subjects into two groups at the twenty-fifth percentile and statistically analyzed various oral conditions in the two groups. Significant differences were found between them in the mean numbers of present, sound, and missing teeth for almost all age groups. Moreover, there were significant differences in tooth-contact area and occlusal force between the two groups. The results of multiple regression analysis revealed that the scores had a stronger correlation with occlusal conditions than number of teeth in 55-year-olds, although the effect teeth-factors had on scores was more significant in 45- to 50-year-old males. Females' scores had a stronger correlation with occlusal conditions than number of teeth in all age groups. These results indicate that the questionnaire on the acceptance of 31 different kinds of food is useful in providing a basis for oral health instruction and dental treatment aimed at improving chewing ability in adults.

Key words: Food acceptance response scores—Percentile curves—Oral condition—Chewing difficulty—Adult population

Introduction

More than 15% of the adult population aged over 40 have reported dissatisfaction with their oral function[6]. Occlusal and chewing ability in this age group may have been changed by dental treatment, tooth loss or periodontal disease. Many attempts have been made to evaluate chewing efficiency using test foods[1,8,9,14,15] and there have been a large number of reports on food acceptance responses (FARs) and oral condition in older

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Table 1 Age and sex distribution in Surveys I and II

	Survey I						Survey II		
	Age						Age		
Sex	20–29	30–39	40–49	50–59	60–64	Total	40–49	50–59	Total
Males	275	257	273	245	129	1,179	59	38	97
Females	292	275	274	266	127	1,234	55	92	147
Total	567	532	547	511	256	2,413	114	130	244

adult populations[3–5,7,10–13,16,17,22,23,26,27]. However, comparatively few investigations have been carried out on the relationship between FARs and oral and occlusal conditions in adult populations[3,4,7,26,27].

FARs are generally evaluated subjectively, with subjects or patients filling in a questionnaire on whether a food is eaten or not. Foods are classified according to how easily they can be chewed. When subjects or patients provide the acceptance response for a food before dental treatment or mass screening, FAR scores can be useful indicators in health education and dental treatment plans. Percentile curves on the number of present teeth have also been demonstrated to be useful in evaluating oral status in adults, and have subsequently been applied in health education[19–21,28].

The percentile curves of the FAR scores in this study were calculated from data from two surveys on adult patients in dental clinics in Chiba City. We divided them into two groups according to the twenty-fifth percentile of FAR scores for all age groups surveyed. We looked at differences between the two groups in terms of oral and occlusal conditions and analyzed what factors determined the FAR scores.

Subjects and Methods

1. Study population

We used data from adults who participated in the first (Survey I) and second (Survey II) dental patient surveys in Chiba City, which were conducted in 1998 and 1999. The surveys were run by the Chiba Dental Association. Informed consent was obtained all participants.

Data were obtained by a questionnaire and standardized oral health examinations. One-hundred fifty-three dentists conducted most of the dental examinations in the surveys. An expert dental examiner periodically calibrated the results obtained by the dental examiners. There were a total of 2,413 participants in Survey I (males: 1,179, females: 1,234) and 244 in Survey II (males: 97, females: 147) (Table 1). We divided both males and females into five age groups at intervals of five years for Survey I (ages 20–64) and into two age groups for Survey II (ages 40–59). We calculated the percentile curves for FAR scores in Survey I and used them to investigate the relationship between oral condition and scores.

Thirty-one different foods were used. Each of these had a different food texture[24] and had been selected in a previous study we did on the elderly[25]. The foods used were boiled eggs, cheese, onion, boiled fish, sliced raw tuna, boiled rice, chikuwa (fish cake), bread, string beans, cabbage, white chicken meat, Chinese cabbage, ham, cookies, kon-nyaku (a gelatinous vegetable starch), cucumber, carrots, kamaboko (steamed fish paste), persimmons, apples, kinpira (chopped burdock root cooked with soy sauce and sesame oil), pork cutlets, rice crackers, sliced raw scallops, rice cakes, caramel, peanuts, French bread, yellow pickled radish, sliced raw octopus, and dried cuttlefish. They were listed in the table in order from soft to hard.

We assigned scores according to the degree of difficulty they reported in chewing the

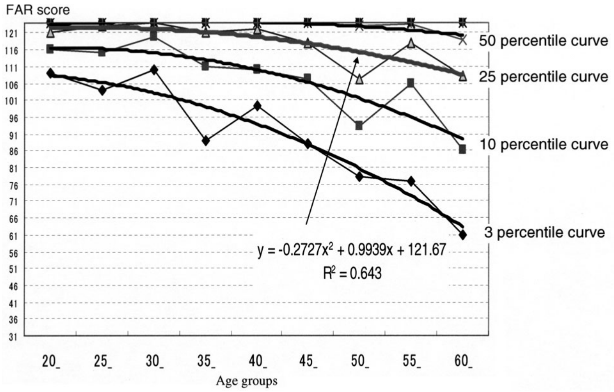

Fig. 1 Percentile curves (polynomial-approximation curves) for FAR scores in males

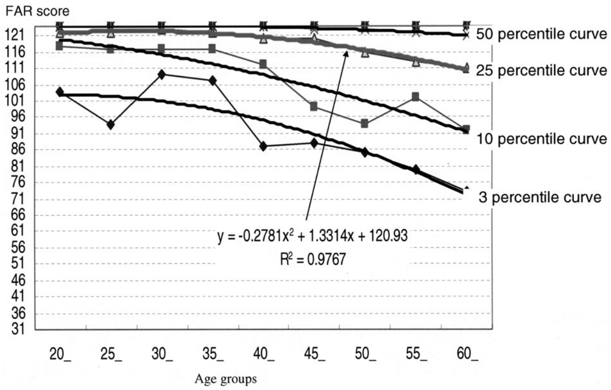

Fig. 2 Percentile curves (polynomial-approximation curves) for FAR scores in females

food. These were 1: cannot be chewed at all, 2: considerable difficulty chewing, 3: some difficulty chewing, and 4: no difficulty chewing. This gave maximum and minimum FAR scores of 124 and 31, and each participant was awarded a personal FAR score.

The FAR scores were discrete data and most subjects had a mean of more than 120 before their 40s. We used FAR percentile curves in this study as oral health indicators for health education under certain limitations. Osada *et al.*[19–21] introduced percentile curves for present teeth, which are also discrete data for use as oral health indicators, and described how to define the percentile values for present teeth. We used their formula to calculate the percentile value of a FAR score as:

$$P(K) = [R(K-1) + R(K)]/2$$

R(K): Cumulative relative frequency at K value for FAR score

P(K): Percentile at K value for FAR score

We calculated the third, tenth, twenty-fifth, fiftieth, and seventy-fifth percentiles for males and females for each of the five age ranges selected to obtain the polynomial expression approximation curves (Figs. 1 and 2). The coefficient of determination of the regression curve for the twenty-fifth percentile was 0.98 for females and 0.64 for males. We did not find any differences between the sexes in the twenty-fifth percentile in any age group. Therefore, we used the same cut-off points to divide the subjects into two groups. The cut-off points were 122 for 20 to 39, 121 for

Table 2 Mean and SD for FAR scores and oral conditions by sex and age group in Survey I

	Males			Females			
Age group	N	mean	SD	N	mean	SD	p-value
FAR scores							
20– 24	138	121.57	4.91	144	121.43	7.54	ns
25– 29	137	121.81	5.10	148	121.21	6.98	ns
30– 34	130	122.44	5.14	138	122.09	4.65	ns
35– 39	127	119.87	9.56	137	121.34	7.46	ns
40– 44	135	120.40	8.32	135	119.50	9.79	ns
45– 49	138	118.38	11.09	139	118.11	11.96	ns
50– 54	119	114.69	14.00	132	116.27	13.23	ns
55– 59	126	117.28	13.92	134	116.11	13.04	ns
60–	129	111.48	17.65	127	114.14	14.16	ns
Teeth present							
20– 24		27.70	1.22		27.51	1.22	ns
25– 29		27.45	1.14		27.16	1.37	ns
30– 34		26.82	1.76		27.00	1.48	ns
35– 39		26.09	2.44		26.37	2.12	ns
40– 44		25.61	3.06		25.24	3.70	ns
45– 49		24.28	4.06		24.39	4.04	ns
50– 54		23.17	4.92		23.25	4.98	ns
55– 59		22.70	6.70		21.22	5.97	0.002
60–		19.71	7.75		19.83	6.78	ns
Sound teeth							
20– 24		14.67	5.28		14.55	5.63	ns
25– 29		13.83	5.63		13.59	5.34	ns
30– 34		11.22	5.69		11.88	5.42	ns
35– 39		12.04	5.09		11.20	5.06	ns
40– 44		12.39	5.68		9.90	5.01	0.0002
45– 49		11.93	6.11		8.88	4.88	<0.0001
50– 54		11.66	5.97		9.16	6.01	0.0013
55– 59		11.87	6.68		8.59	6.10	<0.0001
60–		9.03	6.29		6.63	6.05	0.0006
Missing teeth							
20– 24		0.17	0.42		0.37	1.05	0.044
25– 29		0.41	1.00		0.64	1.26	ns
30– 34		1.02	1.56		0.91	1.45	ns
35– 39		1.65	2.37		1.41	2.09	ns
40– 44		2.21	2.99		2.54	3.73	ns
45– 49		3.51	4.05		3.44	4.06	ns
50– 54		4.75	4.99		4.56	4.95	ns
55– 59		5.20	6.75		6.66	6.02	0.0021
60–		8.12	7.83		7.98	6.83	ns
Mean number of sextants (CPI)							
20– 24		4.13	2.16		2.80	2.35	<0.0001
25– 29		4.56	2.32		3.03	2.42	<0.0001
30– 34		4.69	1.90		3.49	2.45	<0.0001
35– 39		4.34	2.06		3.95	2.29	<0.0001
40– 44		4.67	1.83		4.06	2.08	0.016
45– 49		4.53	1.70		3.90	2.13	0.0217
50– 54		4.39	1.67		3.89	1.92	0.0455
55– 59		4.28	1.95		4.04	1.80	ns
60–		4.02	1.96		3.67	1.96	ns

ns: Not significant

40 to 44, 119 for 45 to 49, 117 for 50 to 54, 114 for 55 to 59, and 110 for 60 to 64. We divided the subjects into two groups and compared them on the basis of indices taken of their respective oral and occlusal conditions.

The indices obtained in the oral examina-

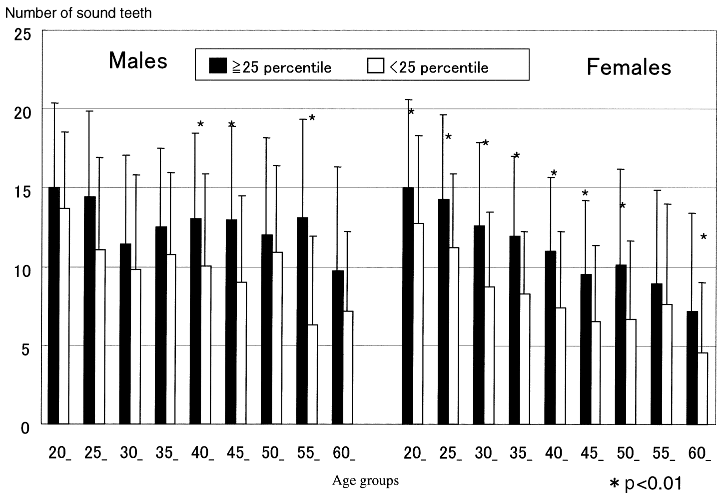

Fig. 3 Mean number of sound teeth classified by FAR scores

tion in Survey I were the number of present or missing teeth, the number of sound teeth, the number of teeth with root caries, the Community Periodontal Index (CPI) code, WHO, and the number of sextants with periodontal disease. The indices in Survey II were occlusal contact area, occlusal pressure, occlusal force, and occlusal balance (left and right, and anterior and posterior) determined using Prescale™ (50H W type, GC Co., Ltd., Tokyo, Japan) in addition to oral condition. Subjects were required to perform maximal clenching with a pressure sheet placed interocclusally. These four indicators were measured with analytical equipment and software (Occluzer™ FPD703, GC Co., Ltd.).

2. Statistical analysis

All statistical analyses were done with the Windows SAS system, Ver. 8.02. The Wilcoxson matched-pairs signed rank test was used to determine differences between the average oral conditions of the two groups classified according to FAR scores. Stepwise multiple linear regressions were used to identify significant confounding factors in variations in oral and occlusal conditions. Multiple logistic regression analysis was used to adjust the results for the confounding effects of age and sex.

Results

1. Oral condition of two groups in Surveys I and II

Significant sex differences were found in the number of sound teeth and the mean number of sextants with periodontal disease (CPI). No significant differences were found for other oral conditions or FAR scores (Table 2).

Figure 3 plots the average number of sound teeth for females within the twenty-fifth percentile (IN25P) and males outside the twenty-fifth percentile (OUT25P) classified by FAR scores for all age groups. There were clearly few sound teeth in the IN25P group across all age groups; indeed, a characteristic feature of the females was the low number of sound teeth.

The average number of present teeth in the two groups is plotted in Fig. 4. A considerable number of subjects aged over 40 in the OUT25P group still had many of their teeth. The percentages of subjects that had not lost any teeth in OUT25P and IN25P were respectively 82.4% and 86.5% in the 20–24 age range, 57.7% and 30% in the 30–34 age range, 36.4% and 3.85% in the 40–44 age range, and 26.6% and 4.9% in the 50–54 age range. There were a number of subjects in the

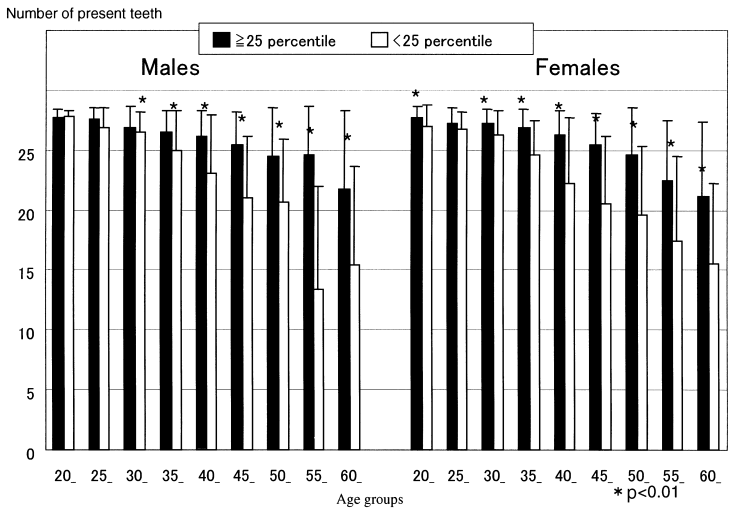

Fig. 4 Mean number of present teeth classified by FAR scores

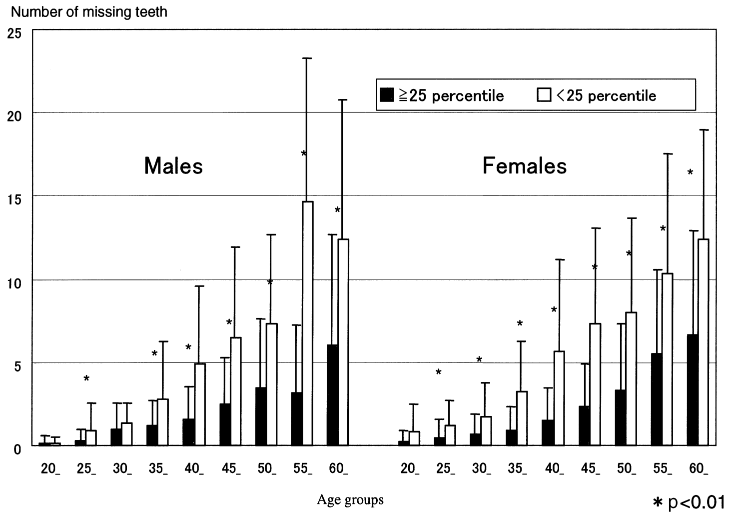

Fig. 5 Mean number of missing teeth classified by FAR scores

IN25P group who had lost more than 10 teeth in the 35–40 age range. In addition, a number of subjects in the 40–45 age range had lost more than 20 teeth. The average number of missing teeth in the two groups is plotted in Fig. 5.

Although the mean number of sextants with periodontal disease was low in the IN25P group in the 40–45 age range, it was also low in both sets of subjects aged over 45 (Fig. 6). However, there were no significant differences between the two groups. Additionally, no significant differences in root caries were found for any of the age groups.

Significant differences were found between the two groups in the mean number of present teeth, missing teeth, and the need for dental treatment for all ages in Survey II. Moreover, in terms of occlusal condition, there were significant differences in the occlusal contact area and occlusal force between the two groups. In particular, there was a

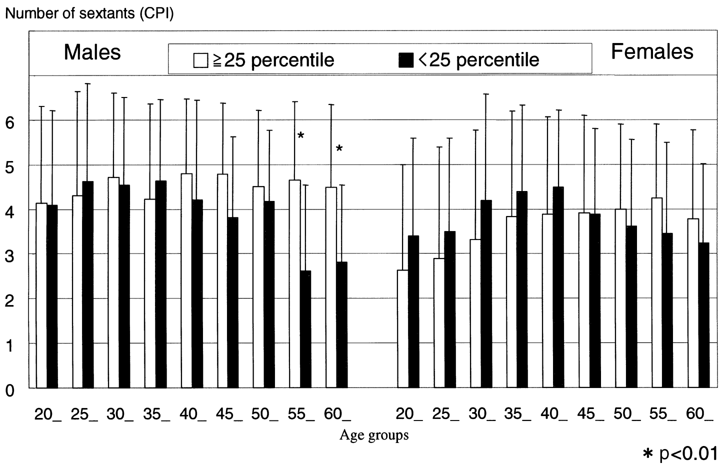

Fig. 6 Mean number of sextants with periodontal disease (CPI) classified by FAR scores

Table 3 Mean indices for oral and occlusal conditions classified by FAR scores (Survey II)

	FAR score ≧122			FAR score <122			
Indices	N	mean	SD[a]	N	mean	SD	p-value
Oral condition							
Teeth present	191	26.44	1.80	50	25.00	3.29	<0.0001
Sound teeth		12.95	6.08		11.20	6.43	ns[b]
Untreated teeth		0.69	1.68		1.10	2.96	ns
Missing teeth		1.51	1.81		2.98	3.30	<0.0001
Missing teeth needing treatment		0.46	0.79		1.40	2.12	<0.0001
Root caries experience		1.51	3.49		0.76	1.91	ns
Mean number of sextants with periodontal disease		2.89	2.33		2.96	2.10	ns
Occlusal condition[c]							
Occlusal contact area	173	29.4	26.5	46	16.7	14.7	0.0021
Occlusal force (N)		65.7	11.0		65.7	14.9	ns
Mean occlusal pressure (MPa)		18.1	15.8		10.5	8.34	0.0019

[a]: Standard deviation, [b]: Not significant, [c]: Measured with Prescale™

significant difference between the average number of missing teeth and the occlusal contact area and occlusal force (Table 3).

2. Multiple regression analyses of FAR scores

1) Oral condition

Multiple regression analysis revealed correlations in a number of age groups between FAR scores, the number of missing teeth and number of sound teeth (Table 4). The number of sound teeth had a particularly strong correlation with the FAR scores in the 20–35 age groups. Correlations between the number of present teeth and FAR scores were only found in the 45–50 age range in males and in the 51–55 age range in females. However, there were no correlations between the FAR score and the presence of root caries or the number of sextants in terms of CPI.

Multiple logistic regression analysis adjusted

Table 4 Multiple regression analysis of oral condition related to FAR scores (Survey I)

Age group	N[a]	Explanatory variables						CD[d]	p-value
		Teeth present	Missing teeth	Missing teeth for TN[b]	Sound teeth	Root caries experience	CPI[c]		
Males									
20– 24	138								
25– 29	137		−3.52[e]		0.18			0.178[e]	<0.0001
30– 34	130				0.23			0.031	<0.045
35– 39	127		−3.13			0.73		0.230	<0.0001
40– 44	135		−1.22	−1.46				0.251	<0.0001
45– 49	138	5.15	3.99	−1.47				0.296	<0.0001
50– 54	119		−1.79	−1.54	−0.77			0.291	<0.0001
55– 59	126		−2.14					0.567	<0.0001
60–	129					−1.60	5.1	0.186	<0.0001
Females									
20– 24	114			−2.19	0.32			0.025	0.012
25– 29	148				0.35			0.028	0.0422
30– 34	138		−1.21		0.20			0.130	<0.0001
35– 39	137		−3.42					0.440	<0.0001
40– 44	135		−1.28	−0.93				0.262	<0.0001
45– 49	139		−2.13					0.268	<0.0001
50– 54	132	1.11					1.29	0.137	<0.0001
55– 59	134	16.56	15.34					0.293	<0.0001
60–	127	0.97		−0.99				0.225	<0.0001

[a]: Number of subjects, [b]: Need for treatment, [c]: Number of sextants with periodontal disease (CPI),
[d]: Coefficient of determination, [e]: Parameter estimates

Table 5 Multiple logistic regression of less than 25 percentile for FAR (Survey I)
(Explanatory covariates: sex, age, PT, RDFT, and CPI)

Explanatory covariates	Parameter estimates	Standard error	Odds ratio (95% CI)*	p-value
Intercept	−0.75	0.23	—	0.0014
Sex	−0.005	0.10	1.00 (0.82–1.21)	0.964
Age	−0.03	0.004	0.97 (0.96–0.98)	<0.0001
PT	1.54	0.12	4.64 (3.64–5.92)	<0.0001
RDFT	0.02	0.14	1.02 (0.79–1.32)	0.864
CPI	0.45	0.11	1.57 (1.26–1.94)	<0.0001

*: 95% confidence interval

Outcome of interest was coded 0: ≧25 percentile for FAR and 1: less than 25 percentile for FAR.
Sex: 1: male and 2: female
PT: 0: ≧25 teeth present
1: <25 teeth present
RDFT: 0: no root caries experience
1: at least one root caries experience
CPI: 0: ≦2 for CPI code
1: more than 3 of CPI code

for age and sex showed that the number of missing teeth, present teeth, and CPI were significantly associated with IN25P (Tables 5 and 6). The odds ratios were 4.64 (3.64–5.92) for those with less than 25 present teeth, and 1.57 (1.26–1.94) for those with a CPI code of more than 3. The odds ratios were 2.70 (2.13–3.43) for those with at least one missing

Table 6 Multiple logistic regression <25 percentile for FAR (Survey I)
(Explanatory covariates: sex, age, MT, RDFT, and CPI)

Explanatory covariates	Parameter estimates	Standard error	Odds ratio (95% CI)*	p-value
Intercept	−1.37	0.22	—	<0.0001
Sex	−0.04	0.10	1.04 (0.85–1.26)	0.7194
Age	−0.02	0.005	0.98 (0.97–0.99)	0.0002
MT	0.99	0.12	2.70 (2.13–3.43)	<0.0001
RDFT	−0.01	0.13	0.98 (0.76–1.28)	0.9141
CPI	0.43	0.11	1.55 (1.26–1.90)	<0.0001

*: 95% confidence interval

Outcome of interest was coded 0: ≧25 percentile for FAR, 1: less than 25 percentile for FAR.
Sex: 1: male, 2: female
MT: 0: no. of missing teeth
1: at least one missing tooth
RDFT: 0: no root caries experience
1: at least one root caries experience
CPI: 0: ≦2 for CPI code
1: >3 for CPI code

Table 7 Multiple regression analysis of oral and occlusal factors related to FAR scores (Survey II)

Age group	N[a]	Explanatory variables						CD[b]	p-value
		Teeth present	Sound teeth	Maximum occlusal force	Balance of occlusal force		Occlusal contact area		
					(Lateral)	(Anterior & posterior)			
Males									
40– 44	28	—	—	—	—	—	—	—	
45– 49	31	0.75[c]	—	—	—	—	—	0.154	0.043
50– 54	23	1.96	−0.33	—	—	—	—	0.762	<0.0001
55– 59	15	—	—	—	−2.1	—	0.03	0.402	<0.14
Females									
40– 44	20	—	—	—	—	—	—	—	
45– 49	35	—	—	—	—	—	—	—	
50– 54	47	0.89	—	1.88	−2.87	—	—	0.336	0.0013
55– 59	45	—	—	0.87	—	−6.23	—	0.590	<0.0001

[a]: Number of subjects, [b]: Coefficient of determination, [c]: Parameter estimates

tooth and 1.55 (1.26–1.90) for those with a CPI code of more than 3.

2) Occlusal conditions

The results of multiple regression analysis revealed that the FAR score had a stronger correlation to occlusal conditions than teeth factors in 55-year-olds (Table 7). In females, the FAR scores had a stronger correlation to occlusal conditions than the number of present teeth and sound teeth in all age groups.

Discussion

Food selection patterns are modified by socioeconomic, cultural, psychological, and metabolic factors. For this reason, Wayler *et al.*[27] used a questionnaire to evaluate taste and texture acceptabilities, the perceived ease of chewing, and frequency of ingestion. Although our questionnaire also included a perceived ease of chewing category, we did not include taste or texture acceptance category.

Sometimes, subjects reported no experience of eating the foods listed in the questionnaire due to dislikes regarding texture or taste, so when no answer was given for one or more of the indicator foods, we excluded those data from the analysis.

The results obtained in this study revealed that subjects with poor oral and occlusal conditions could be screened from the age of 20 by subjective evaluation using this questionnaire. A number of reports have shown that the oral status of older adult subjects can be ascertained comparatively easily with this questionnaire[3,11–13,22]. Our study found that the questionnaire could be used to screen subjects between the ages of 30 to 40 who were at high risk of developing chewing disabilities.

Food acceptance was reported to be more strongly related to the presence of occlusal support or whether dentures were worn than the number of present teeth in the elderly[10,13,22]. Here, however, the number of present or missing teeth, maximal occlusal force, balance of occlusion (lateral and/or anterior-posterior), and occlusal contact area were found to be most strongly related to food acceptance in adults, as shown in Tables 4, 5, and 6. Okiyama *et al.*[18] reported that maximal occlusal force measured with Prescale™ sheets had a strong positive correlation to mastication for standardized indicator foods in those under 40 years old. Lucas and Luke[14] assessed the extent of breakdown of raw carrot in young dentate adults and examined its relation to variations in dentition. They showed that the rate of comminution with increasing numbers of chews was most highly correlated with the occlusal area of post canine teeth before the age of 40. We found similar results in subjects over 50, where occlusal contact area and maximum occlusal force were associated with food acceptance (Table 6). Fujisawa *et al.*[4] examined the relationship between degree of chewing difficulty and oral and occlusal conditions in subjects in their 40s and 50s. They found that the number of residual (present) teeth and bite force were related to the degree of chewing difficulty. However, periodontal status was not related to function, although it was suggested that it might play an important role in satisfaction gained from eating.

We set FAR scores of 121 and 122 as the cut-off points to divide subjects aged 20–44 into two groups. These scores are only 3 and 2 points lower than the maximum possible FAR scores. The scores for the cut-off points in 45-year-old subjects were only 5 to 14 points lower than the maximum FAR scores. Subjects less than 44 years of age who reported difficulty chewing one or two foods had usually lost one or more teeth. In fact, 3.85% had not lost any teeth among the 40–44-year-olds in the IN25P group (data not shown). However, 36.4% in the same group had lost teeth (data not shown).

Locker *et al.*[12] reported that relatively few subjects under the age of 49 had trouble chewing or biting any of the six indicator foods. Only 4.8% of subjects from 30–49 years and 16% from 50–64 years reported difficulty chewing or biting. Gilbert *et al.*[6] found approximately 14% of subjects 45 or older were dissatisfied or very dissatisfied with their ability to chew. Some of the indicator foods used in this study were very hard, such as dried cuttlefish and raw sliced octopus. Therefore, the difficult-to-chew response rate was relatively high in this study. However, these foods are still useful in evaluating oral and occlusal conditions in adults.

The results indicate that subjects with less than 25 present teeth are 3.78 times more likely to belong to the IN25P group. In the Healthy People 2010 project, the oral health target given by the Tokyo Metropolitan Government is 25 present teeth in 50-year-old people. This value is reasonable in view of our subjective evaluations of food acceptance.

Percentile curves can be used in health education to accurately identify oral conditions in relation to age. Subjects aged 50 years with a FAR score of 110 do not have good oral condition and we can predict with some accuracy likely deterioration in those conditions over the next ten years. When a patient's FAR score is assessed in clinics as being within the twenty-fifth percentile, dentists need to examine him or her in detail and determine what dental treatment is required to provide chewing satisfaction. Allen *et al.*[2] investigated satisfaction in patients before and after prosthodontic treatment, including the use of implants, and found many differences in food selection and perception of chewing ability, depending on the kind of prosthesis used. Thirty to fifty percent of subjects who requested and received an implant to stabilize a complete fixed or removable prosthesis and who received full conventional dentures still avoided eating foods such as carrots and apples. It has been suggested that these patients need individualized dietary advice to ensure they receive a satisfactory diet. Therefore, we need to use valid questionnaires based on subjective evaluations to improve dental treatment and provide high-quality oral treatment.

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