[Environmental Health and Preventive Medicine 6, 170–176, October 2001]

Original Article

Occlusal Function Associated with Body Composition in Premenopausal Japanese Women

Shuichi HARA[1], Hisako YANAGI[1], Hitoshi AMAGAI[2] and Shigeo TOMURA[1]

[1]*Institute of Community Medicine, University of Tsukuba, Ibaraki*
[2]*Orthopedics, Department of Physical Therapy, Tsukuba college of Technology, Ibaraki*

Abstract

Objectives: The goal of the present study was to investigate the relationship between occlusal function and body composition in 108 premenopausal healthy Japanese women aged 20–45 years.

Methods: Pressure-sensitive sheets were used to measure occlusal function. Whole fat mass and lean mass, fat-free mass, and whole-bone mineral content were measured by dual-energy X-ray absorptiometry (DXA).

Results: After being adjusted for age and the square of height, the whole lean mass and grip strength of the large occlusal contact-area group were found to be significantly higher than those of the small occlusal area groups ($p<0.05$, respectively). In the 1-year follow-up study, changes in weight in the small-occlusal contact-area group and the low-occlusal force group were significantly larger than other occlusal-contact area or occlusal-force groups. The mean occlusal-contact area and occlusal force were both significantly smaller in subjects with partial dentures than in those without ($p<0.05$).

Conclusion: Large occlusal contact-area, high occlusal force, and no dentures may be associated with some good health conditions in premenopausal Japanese women.

Key words: occlusal-contact area, occlusal force, body composition, pressure-sensitive sheet, premenopause

Introduction

The oral functional system plays an important role in mastication and swallowing as well as in articulation of speech. Tooth loss, the presence of dentures, periodontal attachment loss, and atrophy of the mandible have been reported to be associated with muscle strength[1,2], physical capability[3,4], bone-mineral content or density[5,6], and general health condition[7] in studies of elderly males and postmenopausal females. However, other studies have failed to find such associations[8,9], although only a few studies have investigated the association between occlusal function and body composition among premenopausal females[10,11].

Occlusal force is an important indicator in evaluating oral function. Some previous studies of the elderly have found that occlusal force is associated with age, gender[12], change in occlusal direction[13], the presence of implants or dentures[1], facial morphology[14], and craniomandibular disorders[11]. Most studies have used either transducers or a T-scan system in evaluating occlusal force. Transducers are able to measure the pressure in the area from the canine to the first molar; however, the measurement areas are small and usually only on one side of the jaw[3,4,15]. The T-scan system is able to measure both the magnitude of the bite force and the distribution of occlusal contact; however, this system has only five grades of measured bite force, and occasionally gives misleading reproductions of occlusal contact[16].

Pressure sensitive sheets (Dental Prescale) are available for evaluating occlusal force, occlusal-contact area, and occlusal pressure[17–20]. The use of these sheets has developed as a method for the measurement of occlusal balance or dental implants. Recently, this method was applied to the measurement of occlusal function, demonstrating itself to be useful for general screening purposes[20]. With this method, it takes only a few seconds for subjects to have their occlusal functions measured; they only have to sit and bite the sheets.

We carried out occlusal-function measurements using the pressure-sensitive sheets while measuring the whole fat mass and lean mass, muscle strength, and whole bone mineral content, and investigated oral condition and lifestyle to study the relationships between the occlusal variables and body composition in healthy, premenopausal Japanese females. Our hypothesis was that good occlusal function is associated with good body composition; higher levels of lean mass and fat-free mass, bone mineral content, and sufficient muscle strength. We conducted the present study to verify this hypothesis.

Received Jan. 11 2001/Accepted Apr. 19 2001
Reprint requests to: Hisako YANAGI
Institute of Community Medicine, University of Tsukuba, Tennou-dai 1-1-1 Tsukuba-city, Ibaraki 305-8575, Japan
FAX: +81(298)53-3039
E-mail: hyanagi@md.tsukuba.ac.jp

Materials and Methods

Subjects

We recruited 153 healthy female volunteers aged 16 to 48 years living in a southern area of Ibaraki prefecture, Japan through advertisements in a community newspaper. The study was conducted between July 1, 1996 and March 31, 1999 to examine the genetic and environmental factors affecting body composition in premenopausal healthy women. Among them, we selected 108 subjects with an average age of 33.3±6.7 years (ranging from 20 to 45 years) who underwent the measurements of occlusal function and body composition, and completed a self-administered questionnaire related to lifestyle and oral health. All subjects had regular menstruation, and none had diseases or were on medications affecting body composition (including oral contraceptives).

The Ethics Committee of Tsukuba University Hospital approved the study, and all subjects gave written informed consent.

Methods

Anthropometrical measurements

Height and weight were measured, and body mass index (BMI) was calculated using the formula;

$$[\text{weight (kg)}]/[\text{height (m)}]^2.$$

Measurements of body composition

We measured whole body fat mass, whole lean mass, and whole bone mineral content by dual energy X-ray absorptiometry (DXA) using a DCS-3000 (Aloca Inc. Tokyo, Japan). Subjects were placed in a supine position with both hands placed prone during the measurements. Body composition was calculated using analysis software and an NEC personal computer PC-9801DA (NEC Co., Ltd, Tokyo, Japan). Fat-free mass (kg) was calculated using the formula;

(whole lean mass)+(whole bone mineral content).

To evaluate the coefficients of variation (CV) in our machine, one person underwent a whole-body scan 10 times with repositioning between each scan. The CV for the scanning of whole body fat mass, whole body lean mass, and bone mineral content in our machine was 3.4%, 2.2%, and 1.2%, respectively.

Occlusal function measurements

Occlusal function values were measured using a pressure-sensitive sheet (Dental Prescale 50H type W, Fuji Photo Film Co. Tokyo, Japan), with the occlusal-contact area, average occlusal pressure, and occlusal force being determined. Dental Prescale 50H type W consists of two polyethylene sheets coated with a green wax and with numerous microcapsules containing red dye between the sheets. The correlation between the load applied to the sheet by a calibration device and the readout load from the sheet was 0.981 ($p<0.001$)[18]. The CV values of the pressure-sensitive sheets have been found to be 9.7% for the occlusal-contact area and 11.7% for occlusal force in a previous study measuring adult subjects[17]; in the present study, we found the values to be 6.1% for the occlusal-contact area, 8.2% for average occlusal pressure, and 14.9% for occlusal force in our measurements.

One trained investigator performed the measurements; after a brief orientation, subjects sat on a seat maintaining a Frankfort horizontal approximately parallel to the floor and were told to bite the sensitive sheet for 2 seconds as hard as possible. Three occlusal variables were calculated using the occlusion-analyzing computer FPD-730 (Fuji Photo Film Co., Tokyo, Japan). The area of the colored spot on the sheet determined the occlusal-contact area (mm^2). The average occlusal pressure (MPa) was determined from the average density of the developed red color of each colored spot on the sheet. Deep red was defined as high occlusal pressure. Occlusal force (N) was calculated using the following formula:

(occlusal-contact area)×(average occlusal pressure).

Muscle-strength measurements

The grip strengths of both hands were measured using a hand held dynamometer (Matsushima Ika-Seiki Seisakujo, Tokyo, Japan). Back extensor strength was measured using a strain-gauge dynamometer (TY-300, Yagami Co. Ltd., Tokyo, Japan). Grip strength was recorded as an average of the values determined for both hands.

Health questionnaire

A detailed questionnaire was administered to each participant to obtain information regarding the following: menstruation status, medical history (diseases and fractures), and current medication.

Oral condition and lifestyle

We investigated oral condition and lifestyle using a self-administrated questionnaire and by carrying out a detailed interview for each subject regarding the number of teeth at present, the presence of dental caries, the presence of dentures (including both fixed and removable), periodontal disease (alveolar bleeding or swelling), physical activity in junior high school, senior high school, and at present (exercise hours per week), cups (200 mg) of coffee consumed per week, alcohol intake (drinking or none), and smoking (current, experience, non-smoking).

Current nutritional status

Subjects kept a 3-day dietary record (2 weekdays and 1 weekend day). Each subject recorded all food intake and supplements taken during that 3-day period, including mineral supplements and vitamins. A nutrition analysis program, NUT version 3.0 (Human Science Laboratory, Shiga, Japan), was used to calculate the mean daily nutritional intake for each subject.

The mean daily calcium intake (mg/dl) and total calorie intake (Kcal) for each subject was used in the analysis.

Follow-up study

We performed a 1-year follow-up study to investigate the effects of baseline occlusal function on the change in body composition. We measured and calculated body composition, grip strength, and back extensor muscle strength after approximately 1 year of baseline measurements. The rate of change per year (%/year) for each measurement value was calculated using the following formula:

[(follow-up measurement value)–(baseline measurement value)/(baseline measurement value)]/[(duration days between baseline and follow-up)/365]×100.

Statistical analysis

Values of occlusal function were transformed into log values because they were not normally distributed. Pearson's correlation coefficients were calculated to clarify the association between occlusal function and age, body composition, lifestyle, and nutritional intake.

We divided the occlusal function into three groups by tertile values, defined as "SMALL" (0–3.75 mm^2), "MIDDLE" (3.76–6.73 mm^2), and "LARGE" (≥6.74 mm^2) in the occlusal contact-area groups, "LOW" (0–30.09 MPa), "MIDDLE" (30.10–37.09 MPa), and "HIGH" (≥37.10 MPa) in the average occlusal pressure groups, and "LOW" (0–124.33 N), "MIDDLE" (124.34–241.50 N), and "HIGH" (≥241.51 N) in the occlusal-force groups. One-way ANOVA and a post hoc test (Fischer's PTSD test) were performed to compare the means of the above variables and the 1-year follow up change rate between the three groups of each occlusal variable.

To analyze the independent effects of occlusal function in relation to the body composition, we performed ANCOVA, adjusting for age and the square of height. We also performed ANCOVA adjusting for age, calorie intake per day, and physical activity per week at baseline to compare the change rate per year of height, weight, BMI, and body composition between the three occlusal functional groups. The chi-square test was performed to clarify the association between the three occlusal variable groups and the partial denture or periodontal disease groups (presence or none groups).

All analyses were performed with the statistical software package SPSS version 8.0 for Windows.

Results

The characteristics of the 108 enrolled subjects are shown in Table 1. With regard to BMI, 38.9% of subjects were under 20 kg/m^2, and four subjects (3.7%) were over 24 kg/m^2. Four subjects could not be investigated for the presence of periodontal disease and partial dentures. In 104 subjects, thirty subjects (28.8%) had partial dentures, and 56 subjects (53.8%) had some periodontal disease. Fifty-one (47.2%) subjects were found to participate in some physical activity at present.

Figure 1A–1C shows the correlation between the three occlusal functions. The occlusal contact area was found to have a significantly strong correlation with occlusal force in the linear regression analysis (r=0.970, p<0.001; Fig. 1A). There were no significant correlations between the occlusal force and the average occlusal pressure and contact area in the linear regression (r=–0.119, p=0.220, r=0.123, p=0.203, respectively): However, there was a significant inverse correlation between average occlusal pressure and occlusal-contact area in the cubic regression

Table 1 Characteristics of 108 young premenopausal female subjects

Age (year)*		33.3±6.7
Age groups (%)	20–29 yrs	35 (32.4%)
	31–40 yrs	51 (47.2%)
	40–45 yrs	22 (20.4%)
Weight (kg)*		51.4±5.7
Height (cm)*		157.6±5.3
Body mass index (BMI; kg/m^2)*		20.7±1.8
	<20	42 (38.9%)
	20–23	62 (57.4%)
	24≤	4 (3.7%)
Whole body fat mass (kg)*		17.21±4.35
Whole lean mass (kg)*		36.14±3.92
Fat-free mass (kg)*		38.45±4.33
Whole bone mineral content (kg)*		2.05±0.31
Grip strength (kg)*		29.5±4.7
Back extensor muscle strength (kg)*		68.7±15.1
Occlusal-contact area (mm^2)*		6.59±5.64
Average occlusal pressure (MPa)*		34.8±7.6
Occlusal force (N)*		225.3±188.1
No. of teeth at present*		27.7±2.3
Dental caries, presence		98 (90.7%)
Periodontal disease[a], presence (n=104)		56 (53.8%)
Partial denture[b], presence (n=104)		30 (28.8%)
Current physical activity (hour/wk)*		0.7±1.4
Physical activity at junior high school (hour/wk)*		7.3±7.3
Physical activity at senior high school (hour/wk)*		3.9±6.3
Total energy intake per day (kcal)*		1,853.9±362.1
Calcium intake per day (mg)*		631.7±267.8
Coffee intake (cup/wk)[c]*		7.5±7.4
Current smoking		14 (13.0%)
Current alchohol intake		49 (45.4%)

*Mean±SD.
[a] Defined as the presence of alveolar bleeding or swelling.
[b] Including both fixed and removable dentures.
[c] 1 cup =200 ml

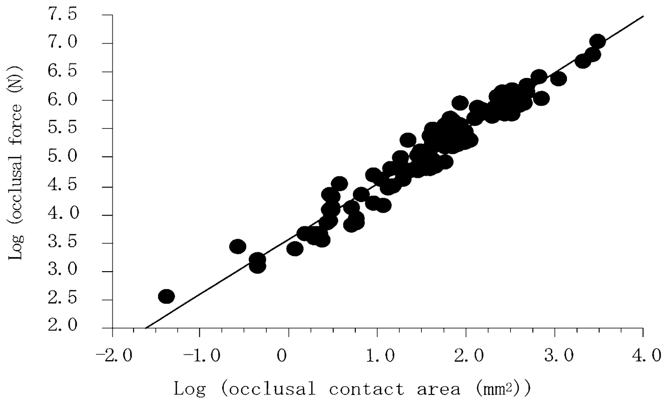

Fig. 1A Correlation between occlusal-contact area and occlusal force. In linear regression analysis, log (occlusal force)=3.569+0.975×(log (occlusal-contact area)). R=0.970 (p<0.001).

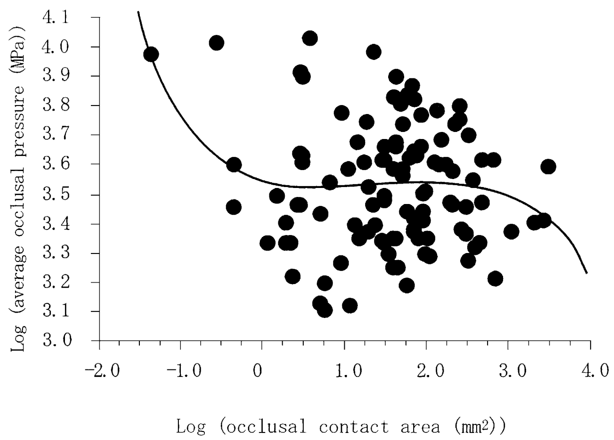

Fig. 1B Correlation between occlusal-contact area and average occlusal pressure. In cubic regression analysis, log (average occlusal pressure)=3.544–0.130×(log (occlusal-contact area))+0.117×(log (occlusal-contact area))^2–0.027×(log (occlusal-contact area))^3; R^2=0.073, F=2.731 (p<0.05).

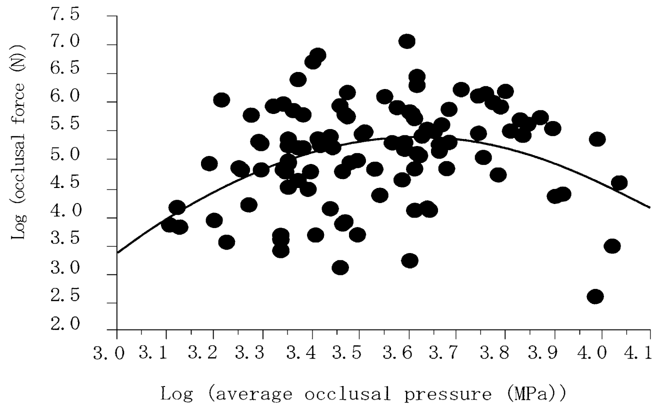

Fig. 1C Correlation between average occlusal pressure and occlusal force. In quadratic regression analysis, log (occlusal force)=–64.207 +38.527×(log (average occlusal pressure))–5.334×(log (average occlusal pressure))^2; R^2=0.12, F=7.158 ($p<0.01$).

analysis (R^3=0.073, F=2.731 $p<0.05$; Fig. 1B). High occlusal-force values were centered within the range of 30–40 MPa of the average occlusal pressure in the quadratic regression (R^2=0.12, F=7.158, $p<0.01$; Fig. 1C).

Table 2 shows the correlation between the three occlusal variables and age, BMI, body composition, lifestyle factors, and nutritional intake. The occlusal contact area was found to correlate positively with the fat-free mass and grip strength ($p<0.05$, respectively). The average occlusal pressure had significantly negative correlations with height, weight, whole body fat mass, whole bone mineral content, and number of present teeth ($p<0.05$, respectively). There was no significant correlation between occlusal force and any other variable.

Table 3 shows a comparison between age and body composition among the three occlusal-function groups by one-way ANOVA and post hoc test, and by ANCOVA adjusted for age and the square of height. In the comparisons of age, BMI, height, weight, present number of teeth, amount of dental caries, total energy intake, and calcium intake, no significances were found between the three groups for occlusal-contact area and occlusal force. Subjects in the LARGE occlusal contact-area group had significantly greater grip strength than those of the other occlusal contact-area group ($p<0.05$), and subjects in the HIGH average occlusal pressure group had significantly greater weight and whole bone mineral content than those of the LOW occlusal contact-area group ($p<0.05$, respectively). There were significant differences in the exercise hours per week in senior high school among the three occlusal-force groups ($p<0.05$).

After adjusting for age and the square of height, the whole lean mass and grip strengths of the LARGE occlusal contact-area group were higher than those of the SMALL occlusal contact-area group ($p<0.05$, respectively). Whole bone mineral content of the HIGH average occlusal pressure group were lower than those ofthe LOW average occlusal pressure group after adjustment for the contributing variables ($p<0.05$, respectively).

Table 4 shows the number and percentage of subjects who had partial dentures or periodontal disease in the occlusal functional groups. Twenty-nine (39.2%) subjects in the LARGE occlusal contact-area group and the HIGH occlusal-force group, and 23 (31.1%) subjects in the HIGH average occlusal pressure group had no partial dentures. In the chi-square test, there were significant associations found between the presence of partial dentures and the occlusal contact-area and occlusal-force groups ($p<0.01$, $p<0.05$, respectively). The mean occlusal-contact area and occlusal force were both smaller in subjects with partial dentures than in those without (5.2±5.9 mm^2 in the partial denture group, and 7.2±5.6 mm^2 in the non-denture group in the occlusal-contact area, $p<0.05$; 185.3±219.9 N in the partial denture group, 241.5±178.8 N in the non-denture group in occlusal force, $p<0.05$).

Seventy-seven subjects participated in the 1-year follow up measurements. Table 5 shows the 1-year change rate (%/year) for body composition and muscle strength in comparison with the baseline occlusal-functional group. The change rates of weight, BMI, and whole fat mass in the SMALL-occlusal contact-area group were significantly larger than those of the LARGE or MIDDLE occlusal contact-area groups before and after adjustments for age, daily calorie intake, and exercise hours per week ($p<0.05$, respectively). The change rates for grip strength and back

Table 2 Pearson's correlation coefficients between occlusal function and age, body composition, lifestyles, and total energy and calcium intakes. (n=108)

	Log (Occlusal-Contact Area)	Log (Average Occlusal Pressure)	Log (Occlusal Force)
Age	–0.055	0.091	–0.030
Height	0.055	–0.207*	0.003
Weight	0.099	–0.269**	0.033
BMI	0.084	–0.181	0.041
Whole body fat mass	–0.001	–0.242*	–0.060
Whole lean mass	0.158	–0.168	0.115
Fat-free mass	0.223*	–0.210*	0.172
Whole bone mineral content	0.030	–0.291**	–0.042
Grip strength	0.203*	–0.148	–0.029
Back extensor muscle strength	0.177	–0.010	0.106
Number of present tooth	0.028	–0.233*	–0.029
Presence of dental caries	0.002	–0.059	–0.013
Exercise hour per week at junior high school	0.053	–0.148	0.015
Exercise hour per week at senior high school	0.050	–0.089	0.026
Exercise hour per week at present	0.151	0.001	0.150
Total energy intake per day	0.099	0.086	0.085
Calcium intake per day	0.163	0.075	0.075

*p<0.05. **p<0.01.

Table 3 Comparison of body compositions by occlusal fanctional groups n=108

	Occlusal-Contact Area Groups			Average Occlusal Pressure Groups			Occlusal Force Groups		
	SMALL	MIDDLE	LARGE	LOW	MIDDLE	HIGH	LOW	MIDDLE	HIGH
	n=36	n=36	n=36	n=36	n=36	n=36	n=36	n=36	n=36
Age (year)*	32.7±6.1	33.4±7.1	33.7±7.1	32.3±6.8	33.9±6.7	33.8±6.8	32.9±6.1	34.5±6.9	32.4±7.2
Height (cm)*	158.3±4.9	156.3±5.7	158.1±5.0	159.0±5.5	157.2±5.5	156.6±4.7	157.7±5.2	156.7±5.6	158.4±5.0
Weight (kg)*	51.3±5.7	50.0±5.3	52.9±5.8	52.9±6.2	51.8±5.6	49.5±4.8[c]	51.1±5.7	51.5±6.0	51.6±5.5
BMI (kg/m^2)*	20.4±1.7	20.5±1.6	21.1±2.1	20.9±2.1	21.0±1.7	20.2±1.5	20.5±1.8	20.9±1.8	20.7±2.0
Number of teeth*	27.3±2.3	28.2±2.4	27.4±2.2	28.3±2.3	27.3±2.4	27.3±2.1	27.4±2.2	28.1±2.4	27.5±2.3
Number of dental caries*	0.1±0.3	0.1±0.3	0.1±0.2	0.1±0.3	0.1±0.3	0.1±0.2	0.1±0.4	0.1±0.3	0.0±0.2
Exercise at junior high school (hr/wk)*	7.4±6.7	7.2±6.7	7.3±8.4	9.0±8.0	6.4±6.8	6.4±6.6	8.0±7.2	6.4±6.0	7.6±8.4
Exercise at senior high school (hr/wk)*	4.4±6.5	2.9±5.4	4.5±7.1	4.5±7.4	4.4±6.0	2.8±5.5	5.9±7.4	2.0±4.2[c]	4.0±6.6
Exercise at present (hr/wk)*	0.3±0.6	0.7±1.2	0.9±1.9	0.4±0.7	0.8±1.9	0.7±1.2	0.3±0.6	0.9±1.9	0.8±1.1
Total energy intakes per day (kcal)*	1,802.8±346.1	1,908.5±379.4	1,852.0±362.9	1,872.4±344.2	1,813.2±358.0	1,876.6±388.9	1,807.6±356.6	1,847.7±350.6	1,906.2±381.5
Calcium intakes per day (mg)*	561.6±215.4	704.4±298.1	631.2±272.2	625.6±267.0	632.1±267.7	637.3±276.1	559.8±231.0	652.4±226.2	683.5±324.9
Whole body fat mass (kg)**	17.44	16.52	17.68	18.10	17.36	16.18	17.68	17.45	16.51
Whole lean mass (kg)**	35.35	36.12	36.96[b]	35.77	36.69	35.97	35.40	36.22	36.80
Fat-free mass (kg)**	37.36	38.92	39.07	38.44	39.21	37.69	37.35	39.10	38.90
Whole bone mineral content (kg)**	2.09	1.99	2.09	2.15	2.03	1.98[b,c]	2.09	2.06	2.01
Grip strength (kg)**	28.4	28.8	31.2[a,b]	29.7	29.4	29.3	28.9	29.3	30.2
Back extensor strength (kg)**	66.6	66.1	72.9	68.4	65.4	72.1	67.1	66.7	71.8

*Mean±SD.
**Mean after adjusting for age and (height)^2
[a] p<0.05 versus MIDDLE group by ANCOVA.
[b] p<0.05 versus SMALL (or LOW) group by ANCOVA.
[c] p<0.05 versus SMALL (or LOW) group by one-way ANOVA and post hoc test.

Table 4 Comparison of dental condition and physical activities between occlusal functional groups (n=104)

	Occlusal-Contact Area Groups					Average Occlusal Pressure Groups					Occlusal Force Groups				
	SMALL	MIDDLE	LARGE	Chi-square*	p-value	LOW	MIDDLE	HIGH	Chi-square*	p-value	LOW	MIDDLE	HIGH	Chi-square*	p-value
Partial denture[a]															
none (n=74)	18 (24.3%)	27 (36.5%)	29 (39.2%)	10.100	0.006	28 (37.8%)	23 (31.1%)	23 (31.1%)	1.177	NS	19 (25.7%)	26 (35.1%)	29 (39.2%)	9.195	0.010
presence (n=30)	17 (56.7%)	7 (23.3%)	6 (20.0%)			8 (26.7%)	11 (36.7%)	11 (36.7%)			17 (56.7%)	7 (23.3%)	6 (20.0%)		
Periodontal diseases[b]															
none (n=48)	17 (35.4%)	15 (31.3%)	16 (33.3%)	0.142	NS	14 (29.2%)	15 (31.3%)	19 (39.6%)	3.794	NS	18 (37.5%)	14 (29.2%)	16 (33.3%)	0.401	NS
presence (n=56)	18 (32.2%)	19 (33.9%)	19 (33.9%)			22 (39.3%)	19 (33.9%)	15 (26.8%)			18 (32.2%)	19 (33.9%)	19 (33.9%)		

*Chi-square test.
[a] Including both fixed and removable dentures.
[b] Periodontal diseases were defined as the presence of alveolar bleeding or swelling.

Table 5 Comparison of the one-year rate change on body composition and muscle strength by baseline occusal fanctional groups n=77

	Occlusal Contact Area Groups			Average Occlusal Pressure Groups			Occlusal Force Groups		
Rate change for a year (%/year)	SMALL	MIDDLE	LARGE	LOW	MIDDLE	HIGH	LOW	MIDDLE	HIGH
	n=26	n=21	n=30	n=27	n=23	n=27	n=28	n=21	n=28
Height*	0.07	0.32	–0.03	–0.03	0.43	–0.02	0.04	0.32	–0.09
Weight*	1.90	–0.84	–1.67[b]	–0.13	–0.33	–0.10	1.22	–0.86[c]	–1.21
BMI*	1.97	–1.34[c]	–1.77[b]	–0.10	–1.04	–0.05	1.29	–1.37	–1.30
Whole body fat mass	3.84	–2.13[b]	0.91	–0.12	2.37	1.65	2.71	–1.66	1.98
Whole lean mass	0.45	1.97	2.10	2.93	0.47	1.13	0.50	2.14	2.03
Fat free mass	0.29	1.72	1.82	2.72	0.21	0.60	0.33	1.89	1.75
Whole bone mineral content	–1.88	–1.88	–2.33	–2.50	–1.80	–1.74	–2.07	–1.74	–2.27
Grip strength	–1.65	2.18	–1.83	–2.12	3.71	–2.93[a]	–1.77	0.40	–0.09
Back extensor muscle strength	0.42	–0.37	–5.87	0.59	3.47	–9.14[a,b,c]	–0.31	–1.68	–4.16

Mean values after adjusting for age, BMI, calorie intake per day, and exercise hours per week at baseline by ANCOVA.
*Mean values after adjusting for age, calorie intake per day, and exercise hours per week at baseline by ANCOVA.
[a] p<0.05 versus SMALL (or LOW) group by ANCOVA.
[b] p<0.05 versus SMALL (or LOW) group by ANCOVA.
[c] p<0.05 versus SMALL (or LOW) group by one-way ANOVA and post hoc test.

extensor strength in the HIGH average occlusal pressure group were also significantly lower than those for the LOW or MIDDLE average occlusal pressure groups after adjustment for contributing variables ($p<0.05$, respectively). The change rate for weight in the LOW-occlusal force group was significantly higher than that for the MIDDLE occlusal force group analyzed by one-way ANOVA and the post hoc test ($p<0.05$).

Discussion

We investigated the associations between occlusal function and body composition in premenopausal Japanese females. We showed that a large occlusal contact-area and high occlusal force are associated with some good health conditions, including high fat-free mass, and high muscle strength after adjusting for the contributing variables. In addition, our 1-year follow-up study showed that the change rates for weight, BMI, and whole fat mass in the small-occlusal contact-area group were significantly higher compared with those in the other occlusal contact-area groups, and the change rate for weight in the low-occlusal force group was significantly higher than that for the middle occlusal force group before and after adjusting for the contributing valuables. Although no other prospective studies have been reported, Kuwano el al.[10] reported a similar relationship between the fat-free mass and bite force in a cross-sectional study among Japanese young women. Since they used a transducer to measure occlusal function, however, they measured the bite force only at the first molars. Since we used pressure-sensitive sheets, we believe that our results show the association between general occlusal function and body composition.

Based on a previous animal study, Fujise et al.[21] reported that mastication activates the histamine neurons in the trigeminal sensory nucleus or posterior hypothalamus and increases the secretion of neural histamine, which plays an important role in the suppression of eating behavior. They also reported that histamine activates the resolution of peripheral fat. It is suggested that good masticatory function may accelerate both the saturation of food intake and the resolution of body fat, possibly resulting in an association between good occlusal function and low body-fat levels and less weight gain, as observed in the present study.

It has been reported that enhancing the occlusal-contact area through the use of mouth protectors is effective in increasing muscular strength and athletic performance levels[22,23]. However, the subjects in those studies were almost all athletes, and there have been very few studies among non-athletes. The present fidings suggest that a large occlusal-contact area is associated with high muscle strength even in general premenopausal females.

Miyahara[24] reported a positive correlation between the teeth-clenching force level and the level of facilitation of soleus muscle activities, and that the facilitation is due to both a descending influence from the higher brain and afferent inputs from the oral structure. He concluded that oral motor activity had a strong influence on bodily motor function. It is suggested that a larger occlusal-contact area may increase masseter muscle activities, and that the activation of other muscles by the masseter muscle may influence body composition.

The presence of partial dentures was also found to correlate negatively with both the occlusal-contact area and occlusal force in the present study. The mean occlusal-contact area and occlusal force were both smaller in subjects with partial dentures than in those without. Although we were not able to investigate the fitting conditions for the subjects' partial dentures, we did observe that unfitted partial dentures might change jaw posture and occlusal balance, resulting in a smaller occlusal-contact area and occlusal force.

We have shown in the present study a strong significant positive correlation between the occlusal-contact area and occlusal force (Fig. 1A). The present findings suggest that a large occlusal-contact area and high occlusal force might be indicative of good occlusal conditions. In contrast, an average occlusal pressure was found to have no correlation with either the occlusal-contact area or occlusal force in linear regressions; however, there were significant correlations in the quadratic and cubic regression analyses Fig. 1B and 1C). In addition, high average occlusal pressure (above 40 MPa, 3.8 when log-transformed) was found to be associated with a small occlusal-contact area. Means±SD of the occlusal-contact area (log-transformed values) were 3.55±2.25 mm^2 (0.92±1.04) in those subjects with a high average occlusal pressure, and 6.97±5.82 mm^2 (1.64±0.81) in other subjects ($p<0.01$, Fig. 1B). It was suggested that those subjects with a small occlusal-contact area also had few occlusal contact points which reflected the high average occlusal pressure. So, it is suggested that the small average occlusal pressure is a better indicator of occlusal function than a high average occlusal pressure, and therefore there were negative associations between the average occlusal pressure and the variables of body composition (Tables 2, 3, and 5).

As mentioned in the introduction, some studies have found an association between good occlusal function and higher bone mass. However, bone mineral content was not found to be positively associated with occlusal function in the present study. Most of these previous studies, however, were carried out among elderly people or postmenopausal females; there have been few studies in premenopausal females. It is suggested that the effects of occlusal function on bone mass is stronger in elderly people than in premenopausal females.

In conclusion, good occlusal performance; a large occlusal-contact area, high occlusal force, and no dentures are associated with good body composition in premenopausal Japanese females. It is suggested that the maintenance of a good occlusal condition from a young age might be beneficial in maintaining good body composition, subsequently leading to general good health and quality of life.

Acknowledgements

This study was supported by a grant for scientific research from the Ministry of Education, Science, Sports and Culture (09772047) and a grant for The Descente and Ishimoto Memorial Foundation for the promotion of sports science (1999). The authors thank all female volunteers who participated in our study; Prof. Hiroshi Yoshida (Oral surgery, Institute of Clinical Medicine, University of Tsukuba) for advice on measurement of the occlusal function using the occlusal sensitive sheet. We also thank to the public health nurses in the southern Ibaraki area, Chiaki Hirano, Kazue Endo, and Yoshika Hayakawa for data collection.

References

1) Garrett NR, Kaurich M, Perez P, Kapur KK. Masseter muscle activity in denture wearers with superior and poor masticatory performance. J. Prosthet. Dent. 1995; 74: 628–636.
2) Garrett NR, Perez P, Elbert C, Kapur KK. Effects of improvements of poorly fitting dentures and new dentures on masseter activity during chewing. J. Prostet. Dent. 1996; 76: 394–402.
3) Braun S, Bantleon HP, Hnat WP, Freudenthaler JW, Marcotte MR, Johnson BE. A study of bite force, part 1: Relationship to various physical characteristics. Angle Orthod. 1995; 65: 367–372.
4) Braun S, Hnat WP, Freudenthaler JW, Marcotte MR, Honigle K, Johnson BE. A study of maximum bite force during growth and development. Angle Orthod. 1996; 66: 261–264.
5) Krall EA, Garcia RI, Dawson-Hughes B. Increased risk of tooth loss is related to bone loss at the whole body, hip, and spine. Calcif. Tissue Int. 1996; 59: 433–437.
6) Bando K, Nitta H, Matsubara M, Ishikawa I. Bone mineral density in periodontally healthy and edentulous postmenopausal women. Ann. Periodontol. 1998; 3: 322–326.
7) Agerberg G, Carlson G. Chewing ability in relation to dental and general health. Acta Odontol. Scand. 1981; 39: 147–153.
8) Elders PJ, Habets LL, Netelenbos JC, van der Linden LW, van der Stelt PF. The relation between periodontitis and systemic bone mass in women between 46 and 55 years of age. J. Clin. Periodontol. 1992; 19: 492–496.
9) Klemetti E, Vainio P. Effect of bone mineral density in skeleton and mandible on extraction of teeth and clinical alveolar height. J. Prosthet. Dent. 1993; 70: 21–25.
10) Kuwano T, Takada H, Washino K, Inaba R, Yumoto Y, Iwata H. An evaluation of the biting force, the body composition and the amount of masticatory action in young females. Nippon Eiseigaku Zasshi 1998; 52: 624–630.
11) Waltimo A, Kononen M. Maximal bite force and its association with signs and symptoms of craniomandibular disorders in young Finnish non-patients. Acta Odontol. Scand. 1995; 53: 254–258.
12) Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta Odontol. Scand. 1977; 35: 297–303.
13) Paphangkorakit J, Osborn JW. Effect of jaw opening on the direction and magnitude of human incisal bite forces. J. Dent. Res. 1997; 76: 561–567.
14) Proffit WR, Fields HW, Nixon WL. Occlusal forces in normal- and long-face adults. J. Dent. Res. 1983; 62: 566–570.
15) McDevitt WE, Warreth AA. Occlusal contacts in maximum intercuspation in normal dentitions. J. Oral Rehabil. 1997; 24: 725–734.
16) Garcia Cartagena A, Gonzalez Sequeros O, Garrido Garcia VC. Analysis of two methods for occlusal contact registration with the T-Scan system. J. Oral Rehabil. 1997; 24: 426–432.
17) Fukuda M. A new system for measuring occlusal force. Nippon Shishubyo-gakkai zasshi 1981; 23: 397–414.
18) Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. J. Dent. Res. 1999; 78: 1336–1344.
19) Matsui Y, Ohno K, Michi K, Suzuki Y, Yamagata K. A computerized method for evaluating balance of occlusal load. J. Oral Rehabil. 1996; 23: 530–535.
20) Suzuki T, Kumagai H, Watanabe T, Uchida T, Nagao M. Evaluation of complete denture occlusal contacts using pressure-sensitive sheets. Int. J. Prosthodont. 1997; 10: 386–391.
21) Fujise T, Yoshimatsu H, kurokawa M, Oohara A, Kang M, Nakata M, Sakata T. Satiation and masticatory function modulated by brain histamine in rats. Proc. Soc. Exp. Biol. Med. 1998; 217: 228–234.
22) Smith SD. Adjusting mouthguards kinesiologically in professional football players. N.Y. State. Dent. J. 1982; 48: 298–301.
23) Gelb H, Mehta NR, Forgione AG. The relationship between jaw posture and muscular strength in sports dentistry: a reappraisal. Cranio 1996; 14: 320–325.
24) Miyahara T, Hagiya N, Ohyama T, Nakamura Y. Modulation of human soleus H reflex in association with voluntary clenching of the teeth. J. Neurophysiol. 1996; 76: 2033–2041.