Journal of Gerontology: MEDICAL SCIENCES
2002, Vol. 57A, No. 9, M616–M620

Relationship Between Dental Occlusion and Physical Fitness in an Elderly Population

Takayuki Yamaga,[1] Akihiro Yoshihara,[1] Yuichi Ando,[2] Yutaka Yoshitake,[3] Yasuo Kimura,[4] Mieko Shimada,[5,6] Mamoru Nishimuta,[5] and Hideo Miyazaki[1]

[1]Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medical and Dental Sciences, Niigata University, Japan.

[2]Department of Oral Science, National Institute of Infectious Diseases, Tokyo, Japan.

[3]Department for Interdisciplinary Studies of Lifelong Sport and Physical Activity, National Institute of Fitness and Sports in Kanoya, Japan.

[4]Faculty of Culture and Education, Saga University, Japan.

[5]Division of Human Nutrition, National Institute of Health and Nutrition, Tokyo, Japan.

[6]Graduate School of Arts and Sciences, College of Arts and Sciences, University of Tokyo, Japan.

Background. The relationship between physical fitness and dental health status in elderly adults is still unknown. The purpose of the present study is to examine the relationship between physical fitness and occlusal condition of natural teeth in the elderly population. The sample consisted of 591 individuals aged 70 years and 158 aged 80 years selected from the registry of residents in Niigata city.

Methods. Hand grip strength (kg), leg extensor strength (kg), leg extensor power (watts), stepping rate (time per 10 seconds), and one-leg standing time with eyes open (seconds) were measured. The Eichner index was used as a measurement of occlusal condition. It was based on existing natural tooth contacts between maxilla and mandible in the bilateral premolar and molar regions and determined the three groups of classification used. In comparing physical fitness with Eichner index, multiple regression models were developed to adjust for variables such as age, gender, height, body weight, past medical history, blood pressure, serum albumin concentration, presence of lower back pain, smoking habit, marital status, and education.

Results. Multiple regression analyses revealed that leg extensor power ($R^2 = .627$, $p < .05$), stepping rate ($R^2 = .159$, $p < .05$), and one-leg standing time with eyes open ($R^2 = .179$, $p < .05$) showed significant correlations with the Eichner index.

Conclusions. Leg extensor power, stepping rate, and one-leg standing time with eyes open are useful indicators in evaluating lower extremity dynamic strength, agility, and balance function, respectively. These findings suggest that dental occlusal condition is associated with lower extremity dynamic strength, agility, and balance function in elderly adults.

AGE-related decline in physical fitness is related to many problems in the elderly population. For example, a reduced lower extremity function is related to an increase of risk for falls (1–3), loss of balance (1), and difficulty with climbing stairs (1,4–6). Therefore, for elders, the maintenance of physical fitness is important to maintain activities of daily living.

The deterioration of dental status with increasing age is not only related to oral function but also to general health. Loss of occlusal support has been found to be related to impaired chewing efficiency and inadequate nutrition (7). Forced expiratory volume was significantly lower in the edentulous than in dentulous, independent of age and gender (8). Furthermore, occlusal status covaried with several background factors such as education, marital status, and past and present smoking habits (9).

Several investigators reported the influences of oral status, particularly occlusal condition, on motor performance and muscle strength of the extremities (10–14). One epidemiological study reported a relationship between occlusal condition with increasing age and physical activity in the entire body (15). Therefore, dental occlusion can exert some influence on motor activity elsewhere in the body.

Generally, many functions of the human body decrease more rapidly in the period from 70 to 80 years old. The turning point in the deterioration of the oral condition and physical fitness also seems to occur in this period. Nonetheless, few gerontological reports have statistically analyzed the relationship between occlusal status and various physical fitness measurements according to age. The aim of the present study is to evaluate the relationship between physical fitness and dental occlusal condition in the Japanese healthy elderly population aged 70 and 80 years old adjusting for several confounders such as medical and sociological factors.

METHODS

Initially, questionnaires were sent to all 6629 inhabitants aged 70 and 80 years old on a registry of residents in Niigata city. The inhabitants were informed of the purpose of this survey and were asked whether they wanted to partici-

pate. Based on the replies, 763 individuals were selected randomly, with approximately equal numbers of each gender for each age group. The examinations were carried out at seven community halls over a period of 12 days. Physical fitness measurements were carried out only for persons who were permissible based on electrocardiogram, blood pressure, or physician's interview. The final sample size for analyses comprised 591 individuals aged 70 years (302 men and 289 women) and 158 individuals aged 80 years (71 men and 87 women).

The five physical fitness tests were preceded by a medical examination. (i) Maximum hand grip strength was measured using a Smedley hand dynamometer (DM-100s, Yagami Inc, Nagoya, Japan) in both the dominant and nondominant hands. The score obtained was the best of the trials for both grip strengths. (ii) Maximal isometric knee extensor strength was determined by a portable chair incorporating a strain gauge connected to a load cell. The subject sat on a seat in a vertical position that was adjusted so he or she sat comfortably with the legs hanging vertically and knees bent at 90°. The test was alternately performed twice on the right and left legs, respectively. Left and right leg extensor strength was summed for this analysis. (iii) Maximal leg extensor power was determined by an isokinetic dynamometer (Aneropress 3500, Combi Co, Tokyo, Japan). The subject was instructed to sit on the seat of the instrument and press his or her feet forward on the plate as fast as possible until the legs were fully extended. The body mass of each was applied as a resistance. The best score of five trials was used for this analysis. (iv) Maximal stepping rate for 10 seconds was used as an index of agility using an industrial stepping rate counter (Stepping Counter, Yagami Inc). The subject was instructed to step alternately as fast as possible with each leg while in a sitting position for 10 seconds. The stepping rate of the left and right leg was summed for this analysis. (v) One-leg standing time with eyes open was also measured. The static balance function was measured with eyes open and arms out, standing on one foot with the other off the floor. The score was either the number of seconds between when the nonpreferred foot was raised and balance was lost (when the subject began to hop around or when the raised foot was lowered to the floor) or when 2 minutes had elapsed. The subjects performed one trial on their right and left feet, respectively, and the best score was recorded. In physical fitness tests, minimum participation rate was 85.0% (637 subjects, leg extensor strength), and maximum was 99.1% (742 subjects, hand grip strength).

Factors that influence physical fitness data, such as height (cm) and body weight (kg), were measured. Furthermore, the following variables were used to analyze in multiple regression models: past medical history (with/without), blood pressure (hypertension/normal), serum albumin concentration (g/dl), presence of lower back pain (present/absent), smoking habit (smoker/nonsmoker), marital status (unmarried/married), and education ($<$10 years/$\geq$10 years). A subject with a past medical history was defined as a person who had ever experienced at least one of cardiac diseases, respiratory tract diseases, cerebrovascular diseases, diabetes, hepatic diseases, or nephric diseases. Hypertension was defined as a systolic blood pressure of 140 mm Hg or greater and/or a diastolic blood pressure of 90 mm Hg or greater according to *WHO-ISH Guidelines for the Management of Hypertension* (16). Serum albumin concentration was measured by colorimetric technique. Past medical history, lower back pain, smoking habit, marital status, and education were determined by the questionnaire.

As an indicator of occlusal conditions, the Eichner index (17) was used. The Eichner index was based on existing natural tooth contacts between maxilla and mandible in the bilateral premolar and molar regions (existence of tooth contact defined as existence of natural tooth in the maxilla and mandible correspondingly). Class A represents contact in all four support zones. Class B represents contact in three to one zone or in the frontal region only. Class C represents an absence of tooth contact. The subject was laid on a bed, and his or her dental status was determined by dentists.

Spearman correlation coefficients between each measurement of physical fitness and the Eichner index were calculated. Furthermore, in evaluating the relationship between the Eichner index and physical fitness adjusted confounding variables, multiple regression analyses were carried out.

As dependent variables, physical fitness measurements that showed statistical significance ($p < .05$) in the correlation analyses were selected. Because one-leg standing time with eyes open did not show normal distribution, subjects were divided at a median and were coded as a dummy variable.

In addition to the Eichner index, age, gender, height, body weight, past medical history, blood pressure, serum albumin concentration, the presence of lower back pain, smoking habit, marital status, and education, were used as independent variables for adjustment. Age, gender, past medical history, blood pressure, the presence of lower back pain, smoking habit, marital status, education, and the Eichner index were also converted to dummy variables. All data were analyzed using StatView 5.0 (SAS Institute Inc, Cary, NC).

Results

Mean values of hand grip strength, leg extensor strength, leg extensor power, and stepping are presented in Table 1. All measurements were significantly higher (analysis of variance, $p < .001$) for the 70-year-olds and men than for the 80-year-olds and women, respectively. The distribution of categorized one-leg standing time with eyes open by age and gender is also shown in Table 1. More 70-year-olds (55.2%) and men (60.1%) than 80-year-olds (16.3%) and women (34.9%) could continue to stand past 40 seconds. These differences were statistically significant (chi-square test, $p < .001$).

Table 2 shows the distribution of the Eichner index classes by age and gender. The percentage of Class C subjects (25.2%) for 70-year-olds was less than for 80-year-olds (64.3%). There was a significant difference (chi-squared test, $p < .001$) when comparing percentages of classes by age.

Spearman correlation coefficients between each physical fitness measurement and the Eichner index by age and gender are shown in Table 3. In the 70-year-old group, grip

Table 1. Descriptive Statistics and Distribution of Subjects According to Each Physical Fitness Measurement

Measure	70-year-old Men	70-year-old Women	80-year-old Men	80-year-old Women
Hand grip strength (kg)*	39.0 ± 5.7 (301)	24.3 ± 3.7 (287)	32.6 ± 5.5 (70)	19.4 ± 3.8 (84)
Leg extensor strength (kg)*	67.6 ± 17.5 (273)	41.9 ± 13.4 (255)	49.7 ± 14.6 (55)	32.1 ± 11.5 (54)
Leg extensor power (W)*	827.4 ± 224.2 (290)	438.4 ± 149.6 (265)	565.3 ± 163.5 (65)	277.6 ± 130.9 (68)
Stepping (time/10 sec)*	79.7 ± 14.1 (294)	70.8 ± 12.5 (274)	70.4 ± 13.9 (65)	61.9 ± 14.1 (71)
One-leg standing time with eyes open (seconds)†				
–19	50 (17.1)	98 (35.9)	39 (60.9)	56 (78.9)
20–39	43 (14.7)	62 (22.7)	10 (15.6)	8 (11.3)
40–119	100 (34.2)	55 (20.1)	12 (18.8)	6 (8.5)
120–	99 (33.9)	58 (21.2)	3 (4.7)	1 (1.4)

*Data of hand grip strength, leg extensor strength, leg extensor power, and stepping are expressed as the mean ± *SD* (number of subjects). There were significant differences (analysis of variance, $p < .001$) in age and gender.

†Data of one-leg standing time with eyes open are expressed as the number of subjects (percentage). There were significant differences (chi-square test, $p < .001$) in age and gender.

strength ($r = .118$, $p < .05$), leg extensor power ($r = .122$, $p < .05$), and one-leg standing time with eyes open ($r = .186$, $p < .01$) were significantly associated with the Eichner index for men, whereas stepping rate ($r = .139$, $p < .05$) and one-leg standing time with eyes open ($r = .135$, $p < .05$) were significant for women. In the 80-year-old group, none of the physical fitness measurements were significantly associated with the Eichner index.

Table 4 shows the results of the multiple regression analysis of each physical fitness measurement excluding leg extensor strength. Data on all regression models were missing for 47 to 49 subjects. In the multiple regression models, the Eichner index showed significant independent effects on leg extensor power (Class A, $p = .031$), stepping rate (Class A, $p = .044$), and one-leg standing time with eyes open (Class A, $p = .022$; Class B, $p = .021$). However, in the multiple regression models of grip strength, the Eichner index was not a significant independent variable.

Discussion

In the present study, the Eichner index was found to be related to leg extensor power, stepping rate, and one-leg standing time with eyes open after adjustment for age and other variables in elderly adults, and coefficients of determination were comparatively high (0.159 to 0.627) in the multiple regression analyses. These results show that occlusal condition is slightly related to several aspects of physical fitness.

The Eichner index was examined as an objective indicator of occlusal condition in this study. In epidemiological studies, the number of teeth present is often used as an indication of oral health (18,19). However, the occlusal conditions vary among individuals with the same number of teeth. The number of teeth present is a poor indicator of occlusal condition. Therefore, in this study, the Eichner index was adopted as a measurement of deterioration in dental state and dental functional impairment.

In the present study, we adopted grip strength, leg extensor strength, leg extensor power, stepping, and one-leg standing time with eyes open as the indices of physical fitness. Physical fitness can be classified roughly into muscle strength, agility, and equilibrium function and can be estimated by the indices used in the present study. In these indices, leg extensor power is an indicator for lower extremity dynamic strength, and stepping rate is an index of agility estimated by the speed of contraction and relaxation of the right and left muscles of the lower extremities. The loss of muscle power of the lower extremities can have an important impact on the ability to perform activities of daily living such as walking and stair climbing (20–22). Furthermore, the test of standing on one leg with eyes closed has been frequently used to evaluate the balance function, but this method has an increased risk of falling. It is difficult to evaluate individual differences in the elderly population due to small differences in results (6). Therefore, in the present study, we used the test of standing on one leg with eyes open to evaluate the equilibrium function.

In this investigation, although the relevance was very low, one-leg standing time with eyes open had the strongest relation with the Eichner index. Some relation between occlusion and posture regulation has been reported (23,24). Abnormal habituations such as a one-side masticatory may be precipitated by a change of occlusal support. Subsequently, abnormal habituations may lead to a disequilibrium

Table 2. Distribution of Subjects According to Eichner Index Classes

Eichner Index	70-year-old Men	70-year-old Women	80-year-old Men	80-year-old Women
Class A	80 (26.6)	74 (25.8)	4 (5.7)	8 (9.5)
Class B	143 (47.5)	143 (49.8)	24 (34.3)	19 (22.6)
Class C	78 (25.9)	70 (24.4)	42 (60.0)	57 (67.9)

Note: Data are presented as the number of subjects (percentage). There were significant differences (chi-square test, $p < .001$) in age.

Table 3. Correlations Between Each Physical Fitness Measurement and Eichner Index by Age and Gender

Measure	70-year-old Men	70-year-old Women	80-year-old Men	80-year-old Women
Grip strength	0.118* (301)	−0.011 (287)	−0.108 (70)	−0.027 (84)
Leg extensor strength	0.057 (273)	−0.009 (255)	−0.040 (55)	0.188 (54)
Leg extensor power	0.122* (290)	0.089 (265)	0.026 (65)	0.164 (68)
Stepping rate	0.021 (294)	0.139* (274)	−0.078 (65)	0.106 (71)
One-leg standing time with eyes open	0.186** (292)	0.135* (273)	−0.224 (64)	0.105 (71)

Notes: Correlations between physical fitness measurements and Eichner index are presented as Spearman correlation coefficients (number of subjects).
*$p < .05$; **$p < .01$.

of systemic muscle balance and may have some influence on systemic equilibrium function. However, there is not much in the literature that can explain clearly the relation of occlusion to equilibrium function.

There were great differences by age according to all physical fitness measurements and occlusal condition in the present study. These results suggest that elders' physical fitness and occlusal condition may decline gradually with the same frequency, and it is noted that these changes appear in a certain period from 70 to 80 years old. Our results clearly demonstrate the independent association between dental occlusion and physical fitness in healthy elderly subjects. However, because the study model was cross-sectional in nature, it was difficult to prove the causal relationships. Therefore, detailed survey, including future longitudinal study, will be required to inspect the turning points of occlusal condition and physical fitness.

In conclusion, these findings suggest that occlusal condition was related to some physical fitness in the elderly population, independent of several confounding factors such as age, gender, and medical and sociological factors.

Acknowledgments

The work regarding physical fitness of this study was supported by a Grant-in-Aid for Research on Health Services (10150201) (Y. Yoshitake) from the Ministry of Health and Welfare of Japan.

Address correspondence to Takayuki Yamaga, DDS, PhD, Division of Preventive Dentistry, Department of Oral Health Science, Graduate School of Medical and Dental Sciences, Niigata University, 2-5274, Gakkocho-Dori, Niigata, 951-8514, Japan. E-mail: gamaya@dent.niigata-u.ac.jp

Table 4. Multiple Regression Analysis of Each Physical Fitness Measurement

	Dependent Variables							
	Hand Grip Strength		Leg Extensor Power		Stepping Rate		One-Leg Standing Time With Eyes Open	
Independent Variables	β	*p*	β	*p*	β	*p*	β	*p*
Age								
80 years old	−0.170	<.000	−0.222	<.000	−0.182	<.000	−0.284	<.000
Gender								
Female	−0.616	<.000	−0.534	<.000	−0.236	0.000	−0.307	<.000
Height (cm)	0.163	<.000	0.047	0.294	0.133	0.043	0.028	0.667
Body weight (kg)	0.157	<.000	0.262	<.000	0.013	0.783	−0.155	0.001
Past medical history								
With	−0.065	0.001	−0.023	0.352	−0.015	0.693	−0.085	0.020
Blood pressure								
Hypertension	0.047	0.013	0.071	0.004	0.039	0.283	−0.008	0.816
Albumin (g/dl)	0.054	0.005	0.046	0.063	0.038	0.301	0.019	0.595
Lower back pain								
Present	−0.033	0.080	−0.080	0.001	−0.071	0.051	−0.103	0.004
Smoking habit								
Smoker	−0.011	0.603	−0.065	0.014	−0.111	0.005	−0.050	0.200
Marriage								
Married	0.015	0.488	0.022	0.423	−0.027	0.514	−0.001	0.980
Education								
≥10 years	−0.011	0.578	0.019	0.449	0.018	0.629	−0.012	0.751
Eichner index								
Class B	0.002	0.931	0.026	0.378	0.054	0.213	0.100	0.021
Class A	0.018	0.426	0.063	0.031	0.087	0.044	0.098	0.022
Number of subjects	693*		641*		656*		652*	
Coefficient of determination (R^2)	0.761		0.627		0.159		0.179	

Notes: β shows standardized partial regression coefficients.
*Data on all models were missing in 47 to 49 subjects.

References

1. Grabiner MD, Enoka RM. Changes in movement capabilities with aging. *Exerc Sport Sci Rev.* 1995;23:65–104.
2. Gehlsen GM, Whaley MH. Falls in the elderly: part II, balance, strength, and flexibility. *Arch Phys Med Rehabil.* 1990;71:739–741.
3. Tinetti ME, Speechley M, Ginter SF. Risk factors for falls among elderly persons living in the community. *N Engl J Med.* 1988;319:1701–1707.
4. Bassey EJ, Fiatarone MA, O'Neill EF, et al. Leg extensor power and functional performance in very old men and women. *Clin Sci (Colch).* 1992;82:321–327.
5. Rantanen T, Era P, Heikkinen E. Maximal isometric strength and mobility among 75-year-old men and women. *Age Ageing.* 1994;23:132–137.
6. Yoshitake Y, Matsumura Y, Shimada M, et al. Relationship between physical fitness and functional performances in older women. In: Sato M, Tokura H, Watanuki S, eds. *Recent Advances in Physiological Anthropology.* Fukuoka, Japan: Kyushu University Press; 1999:299–308.
7. Österberg T, Steen B. Relationship between dental state and dietary intake in 70-year-old males and females in Göteborg, Sweden: a population study. *J Oral Rehabil.* 1982;9:509–521.
8. Summers CJ, Oberman A. Association of oral disease with 12 selected variables. II. Edentulism. *J Dent Res.* 1968;47:594–598.
9. Österberg T, Hedegård B, Säter G. Variation in dental health in 70-year-old men and women in Göteborg, Sweden. A cross-sectional epidemiological study including longitudinal and cohort effects. *Swed Dent J.* 1984;8:29–48.
10. Bates RE, Atkinson WB. The effects of maxillary MORAs on strength and muscle efficiency tests. *J Craniomandibular Practice.* 1983;1:37–42.
11. Williams MO, Chaconas SJ, Bader P. The effect of mandibular position on appendage muscle strength. *J Prosthet Dent.* 1983;49:560–567.
12. Vergan EM, Groppel JL, Pfautsch EW, Ramseyer GC. The effects of mandibular orthopedic repositioning appliance on shoulder strength. *J Craniomandibular Practice.* 1984;2:232–237.
13. Forgione AG, Mehta NR, McQuade CF, Westcott WL. Strength and bite, Part 2: testing isometric strength using a MORA set to a functional criterion. *J Craniomandibular Practice.* 1992;10:13–20.
14. Ishijima T, Hirai T, Koshino H, et al. The relationship between occlusal support and physical exercise ability. *J Oral Rehabil.* 1998;25:468–471.
15. Österberg T, Mellström D, Sundh V. Dental health and functional ageing. A study of 70-year-old people. *Community Dent Oral Epidemiol.* 1990;18:313–318.
16. Guidelines Subcommittee. 1999 World Health Organization-International Society of Hypertension Guidelines for the Management of Hypertension. *J Hypertens.* 1999;17:151–183.
17. Eichner K. Über eine Gruppeneinteilung des Lückengebisses für die Prothetik. *Dtsche Zahnärztl Z.* 1955;10:1831–1834.
18. Miura H, Araki Y, Umenai T. Chewing activity and activities of daily living in the elderly. *J Oral Rehabil.* 1997;24:457–460.
19. Agerberg G, Carlsson GE. Chewing ability in relation to dental and general health. *Acta Odontol Scand.* 1981;39:147–153.
20. Aniansson A, Rundgren A, Sperling L. Evaluation of functional capacity in activities of daily living in 70-year-old men and women. *Scand J Rehabil Med.* 1980;12:145–154.
21. Brown M, Sinacore DR, Host HH. The relationship of strength to function in the older adult. *J Gerontol Med Sci.* 1995;50A:M55–M59.
22. Young A, Skelton DA. Applied physiology of strength and power in old age. *Int J Sports Med.* 1994;15:149–151.
23. Yamashita R, Suenaga H, Yamabe Y, Torisu T, Fujii H. Propagation of various tooth impacts in the human body. *J Oral Rehabil.* 1998;25:785–791.
24. Milani RS, De Periere DD, Lapeyre L, Pourreyron L. Relationship between dental occlusion and posture. *J Craniomandibular Practice.* 2000;18:127–134.

Received December 5, 2001
Accepted April 16, 2002