Relationship Between Dental Occlusion and Physical Fitness in an Elderly Population

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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.

A GER-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-
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, Yamagami 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, Yamagami 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/≥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, and education were determined by the questionnaire.

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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 occlusal condition and posture regulation has been reported (23, 24).

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<table>
<thead>
<tr>
<th>Measure</th>
<th>70-year-old Men</th>
<th>70-year-old Women</th>
<th>80-year-old Men</th>
<th>80-year-old Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand grip strength (kg)*</td>
<td>39.0 ± 5.7 (301)</td>
<td>24.3 ± 3.7 (287)</td>
<td>32.6 ± 5.5 (70)</td>
<td>19.4 ± 3.8 (84)</td>
</tr>
<tr>
<td>Leg extensor strength (kg)*</td>
<td>67.6 ± 17.5 (273)</td>
<td>41.9 ± 13.4 (255)</td>
<td>49.7 ± 14.6 (55)</td>
<td>32.1 ± 11.5 (54)</td>
</tr>
<tr>
<td>Leg extensor power (W)*</td>
<td>827.4 ± 224.2 (290)</td>
<td>438.4 ± 149.6 (265)</td>
<td>565.3 ± 163.5 (65)</td>
<td>277.6 ± 130.9 (68)</td>
</tr>
<tr>
<td>Stepping (time/10 sec)*</td>
<td>79.7 ± 14.1 (294)</td>
<td>70.8 ± 12.5 (274)</td>
<td>70.4 ± 13.9 (65)</td>
<td>61.9 ± 14.1 (71)</td>
</tr>
</tbody>
</table>

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)

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

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.
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.

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

<table>
<thead>
<tr>
<th>Measure</th>
<th>70-year-old Men</th>
<th>70-year-old Women</th>
<th>80-year-old Men</th>
<th>80-year-old Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip strength</td>
<td>0.118* (301)</td>
<td>-0.011 (287)</td>
<td>-0.108 (70)</td>
<td>-0.027 (84)</td>
</tr>
<tr>
<td>Leg extensor strength</td>
<td>0.057 (273)</td>
<td>-0.009 (255)</td>
<td>-0.040 (55)</td>
<td>0.188 (54)</td>
</tr>
<tr>
<td>Leg extensor power</td>
<td>0.122* (290)</td>
<td>0.089 (265)</td>
<td>0.026 (65)</td>
<td>0.164 (68)</td>
</tr>
<tr>
<td>Stepping rate</td>
<td>0.021 (294)</td>
<td>0.139* (274)</td>
<td>-0.078 (65)</td>
<td>0.106 (71)</td>
</tr>
<tr>
<td>One-leg standing time with eyes open</td>
<td>0.186** (292)</td>
<td>0.135* (275)</td>
<td>-0.224 (64)</td>
<td>0.105 (71)</td>
</tr>
</tbody>
</table>

Notes: Correlations between physical fitness measurements and Eichner index are presented as Spearman correlation coefficients (number of subjects).

*p < .05; **p < .01.

Table 4. Multiple Regression Analysis of Each Physical Fitness Measurement

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Hand Grip Strength</th>
<th>Leg Extensor Power</th>
<th>Stepping Rate</th>
<th>One-Leg Standing Time With Eyes Open</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>p</td>
<td>β</td>
<td>p</td>
</tr>
<tr>
<td>Age</td>
<td>-0.170</td>
<td>&lt;.000</td>
<td>-0.222</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>-0.616</td>
<td>&lt;.000</td>
<td>-0.534</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>0.163</td>
<td>&lt;.000</td>
<td>0.047</td>
<td>0.294</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>0.157</td>
<td>&lt;.000</td>
<td>0.262</td>
<td>&lt;.000</td>
</tr>
<tr>
<td>Past medical history</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>With</td>
<td>-0.065</td>
<td>0.001</td>
<td>-0.023</td>
<td>0.352</td>
</tr>
<tr>
<td>Blood pressure</td>
<td>0.047</td>
<td>0.013</td>
<td>0.071</td>
<td>0.004</td>
</tr>
<tr>
<td>Hypertension</td>
<td>0.054</td>
<td>0.005</td>
<td>0.046</td>
<td>0.063</td>
</tr>
<tr>
<td>Albumin (g/dl)</td>
<td>0.015</td>
<td>0.488</td>
<td>0.022</td>
<td>0.423</td>
</tr>
<tr>
<td>Lower back pain</td>
<td>-0.033</td>
<td>0.080</td>
<td>-0.080</td>
<td>0.001</td>
</tr>
<tr>
<td>Present</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking habit</td>
<td>-0.011</td>
<td>0.603</td>
<td>-0.065</td>
<td>0.014</td>
</tr>
<tr>
<td>Smoker</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marriage</td>
<td>0.015</td>
<td>0.488</td>
<td>0.022</td>
<td>0.423</td>
</tr>
<tr>
<td>Married</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education ≤10 years</td>
<td>-0.011</td>
<td>0.578</td>
<td>0.019</td>
<td>0.449</td>
</tr>
<tr>
<td>Eichner index</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Class B</td>
<td>0.002</td>
<td>0.931</td>
<td>0.026</td>
<td>0.378</td>
</tr>
<tr>
<td>Class A</td>
<td>0.018</td>
<td>0.426</td>
<td>0.063</td>
<td>0.031</td>
</tr>
</tbody>
</table>

Number of subjects: 693* 641* 656* 652*
Coefficient of determination (R²): 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


Received December 5, 2001
Accepted April 16, 2002