Original Article

Relationships between the Occlusal Force and Physical/Cognitive Functions of Elderly Females Living in the Community

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Abstract. [Purpose] The present study, was conducted to examine the occlusal force and physical, cognitive, and attentional functions of elderly females living in the community to evaluate the significance of measuring the occlusal force. [Subjects and Methods] The number of subjects was 104. The Occlusal Force Meter GM10 was used to measure their occlusal force. Their physical functions were assessed using eight examinations, including the 30-second Chair Stand Test, and the cognitive functions of the Mini-Mental State Examination and attention functions of the Trail Making Test. [Results] Significant correlations were noted between the occlusal force and all measurements, except for the results of forward bending in a sitting position. Multiple regression analysis was conducted with the occlusal force as an objective variable, and significant partial correlations were noted with the 30-second Chair Stand Test. [Conclusion] These results suggest that it is necessary to provide the elderly with comprehensive support focusing on maintaining their occlusal force, as a nursing care-prevention measure, to help them continue to live a healthy, independent life.
Key words: Occlusal force, Physical functions, Cognitive functions

INTRODUCTION

The population of Japan is aging at a rate faster than in any other country, with the population of the elderly aged 65 years or older accounting for approximately 23% of the total[1)]. As the population ages, medical expenses in Japan are predicted to markedly increase[2)]. It is therefore an important task for Japan, which has the highest mean life expectancy in the world, to reduce medical expenses. To this end, it is important to prevent decreases in the physical and cognitive functions of elderly people by helping them maintain their health and continue to live an independent daily life. The independent intake of meals is a necessary element. Eating food is not only a means of nutritional intake. It is also expected to motivate people to become active as a psychological effect.

Mastication is the process in which food taken into the mouth, is mixed with saliva, and swallowed. An important element of masticatory ability is the occlusal force[3)].

The occlusal force is that applied by the teeth when chewing food, and it is basically generated by the masticatory muscles and is associated with grip strength and leg muscles strength. Recent studies have reported that masticatory and ingestion-related functions influence the physical and cognitive functions of a person[4–6)], although most of those studies involved athletes. Previous studies, mostly questionnaire surveys, involving the elderly, such as research conducted by Strauss et al.[7)], have suggested that a decrease in the occlusal force reduces the pleasure of having meals[8–12)]. It is not unusual for the elderly to have difficulty eating something that they used to be able to ingest without difficulty because of a loss of teeth, the rotating movement of the tongue, and a decrease in salivary secretion as they become older. In fact, some studies have reported that the level of subjective oral health, determined using a scale focusing on masticatory ability, is related to that of general health[13, 14)]. Although previous studies have suggested that a decrease in masticatory ability is associated with aging, few objective data analyses have been conducted to examine the relationships between the occlusal force and physical, cognitive, and attention functions. The present study comprehensively assessed the physical functions of elderly females living independently in the community with the ability to ingest normal meals. We made measurements of the strength of the arm and leg muscles,

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walking ability, standing balance, the Mini-Mental State Examination (MMSE) score (a test designed to evaluate cognitive functions)[10], and the Trial Making Test (TMT) score (a test to assess attention functions)[11], and examined the relationships between them.

SUBJECTS AND METHODS

The subjects were 104 elderly females without severe decrease in cognitive function who participated in a session for measurement of physical fitness organized and held in September 2012 by a municipal government in Japan. They were able to eat normal meals and completed all of the physical tests. The mean age, height, and weight of the subjects were 74.6 ± 5.7 years old, 150.5 ± 14.0 cm, and 51.6 ± 7.5 kg, respectively.

As the present study subjects were healthy elderly females, none of them had any chronic illnesses, apart from a few with histories of hypertension or low back pain.

The subjects were all females because it is inappropriate to analyze male and female subjects with varying levels of physical fitness at the same time.

In consideration of research ethics, the purposes and procedures of the study were explained to and understood by the subjects. An explanation was given that the data collected would not be used for any purpose other than research, and that careful attention would be given to prevent personal information from being disclosed. Prior to obtaining consent from the subjects, verbal and written explanations were given that their participation in the study was voluntary, and that they would never be disadvantaged by refusing to participate. This study received the approval of the Ethical Review Board of the Nishikyushu University (approval number 216).

An occlusal force meter, GM10 (Nagano Keiki Co., Ltd.), was used to measure the occlusal force. The maximum occlusal forces applied by the functioning left and right first molars (including remaining teeth, prostheses, and dentures) were measured twice, and the highest values were recorded for each person.

A digital hand grip dynamometer (Takei Scientific Instruments Co., Ltd.) was used to measure grip strength. The maximum grip strength of the dominant hand of each subject was measured twice while they stood with their arms by their arms by her sides, and the best performance was recorded as the maximum grip strength (kg).

The strength of each of the left and right quadriceps was measured twice, using a hand-held dynamometer (isometric muscle measurement equipment µTas F-1, ANIMA Corporation), while the subjects were sitting with their knees flexed joints bent at 90 degrees, and the best performance (kg) was recorded. The sensor pad was fixed in place using a belt, and attention was paid to ensure that the buttocks were in contact with the chair to increase the reproducibility of the experiment.

In the sit-up test, the subjects first lay down on their backs, with their arms folded in front of the body and knees flexed at 90 degrees.Then, they sat up as many times as possible in 30 seconds while the examiner pressed down on

Table 1. Measurements and test scores of the 104 elderly female subjects

Elderly females (N=104)	
Age (years old)	74.6 ± 5.7
Occlusal force (N)	232.7 ± 181.2
Grip force (kg)	21.4 ± 4.0
Strength of the quadriceps (kg)	17.3 ± 4.4
Sit-ups (number of times)	3.8 ± 5.0
Length of forward bending in a sitting position (cm)	34.2 ± 8.3
Single leg standing time (seconds)	36.3 ± 37.7
Walking speed (meters/second)	2.8 ± 0.5
TUG (seconds)	6.4 ± 1.2
Walking time of a 10-meter obstacle course (seconds)	7.7 ± 1.7
CS-30 (number of times)	18.4 ± 5.4
MMSE (points)	27.4 ± 2.6
TMT (seconds)	115.2 ± 46.3

Mean ± SD

their knees.

To assess the flexibility of the body, a digital device measuring the forward-bending test in a sitting position (Takei Scientific Instruments Co., Ltd.) was used. In the test, the subjects sat on the floor with their legs straight and the back of the head and lower back in contact with a wall, and stretched their arms out straight and placed their hands on the edge of the measuring device placed in front of them. The subjects bent their upper body forward so that they could move the device as far from the wall as possible. The test was performed twice, and the greatest distance was recorded.

The period of being able to stand on one (left or right) leg with the eyes open was measured twice each, using a digital stop-watch, and the longest time was recorded. During measurement, the subjects stood barefoot with their arms beside the body, and gazed at a point level with their eyes two meters in front them. The test was discontinued if there was a change in the base of support or the subject could not keep their arms beside their body.

For the measurement of walking speed, the subjects were asked to walk along a flat, eleven-meter course as fast as they could, and the time taken to walk along a five-meter segment was measured twice using a digital stop-watch. The fastest time (meters/sec in Table 1) was adopted as the walking speed.

In the 10-meter obstacle walking test, the subjects walked along a straight 10-meter course with six 20-cm-high sponge obstacles placed along the course at intervals of 2 meters as fast as they could. The time required to finish the course was measured twice using a digital stop-watch, and the fastest time (seconds) was adopted as the walking time.

In the CS-30 test[15], the subjects first sat down on a chair with their arms folded. When they were told to "start", they immediately stood up straight, sat down on the chair again,

Table 2. Simple correlations between the occlusal force of the 104 elderly female subjects and their other measurements

Elderly females (N=104)	
Grip force (kg)	0.29**
Strength of the quadriceps (kg)	0.25*
Sit-ups (number of times)	0.25*
Length of forward bending in a sitting position (cm)	0.16
Single leg standing time (seconds)	0.22*
Walking speed (meters/second)	−0.35**
TUG (seconds)	−0.29**
Walking time of a 10-meter obstacle course (seconds)	−0.31**
CS-30 (number of times)	0.40**
MMSE (points)	0.30**
TMT (seconds)	−0.23*

**p<0.01, *p<0.05

and repeated this for 30 seconds. However, if it took more than 30 seconds for a subject to stand up, the time was not recorded.

The MMSE was used to assess cognitive function. The MMSE consists of eleven items, and is a simple test designed to assess cognitive function and memory skills; its questions are asked orally. The highest score is 30 points, and examinees with a total score of 21 or lower are considered to have cognitive disorders.

The TMT was used to assess attentiveness. The test is primarily designed to assess selective visual attention functions, and its reliability and validity have been established. The time required to complete the TMT was measured and adopted as an index: the shorter the time, the higher the level of attentiveness.

A statistical analysis of the results of the 104 subjects was conducted to examine the relationships between the occlusal force and measurements using other tests, as assessed by Pearson's correlation coefficient. Items independently related to the occlusal force were extracted using the stepwise (step-down procedure) method of multiple regression analysis, with the occlusal force as the objective variable, and grip force, strength of the quadriceps, number of times in the sit-up test, length of forward bending in a sitting position, single leg standing time, walking speed, time in the 10-meter obstacle walking test, CS-30, MMSE, and TMT scores as explanatory variables. SPSS16.0 was used for statistical analysis, with a significance level of 5%.

RESULTS

Table 1 shows the mean scores and standard deviations of the 104 elderly female subjects' test scores and function measurements, and Table 2 shows the results of simple analysis of the correlation between the occlusal force and the other measures. The correlation coefficients between the occlusal force and the other measures were as follows: grip force (r=0.29, p<0.01), strength of the quadriceps (r=0.25,

p<0.01), sit-ups (r=0.25, p<0.0015), length of forward bending in a sitting position (r=0.16, not significant), single leg standing time(r=0.22, p<0.05), walking speed (r=−0.35, p<0.01), walking time of the 10-meter obstacle walking test (r=−0.31, p<0.01), CS30 (r=0.40, p<0.01), MMSE (r=0.30, p<0.01), and TMT (r=−0.23, p<0.05). Significant correlations were noted between the occlusal force and all the measures, except that of the sitting-position forward-bending test. The stepwise method of multiple regression analysis was performed. Only one item, the CS-30, was identified as a factor independently related to the occlusal force, and the standard partial regression coefficient was 0.44 (p<0.01). The multiple regression equation was: Occlusal force = −35.67 + (15.06 × CS-30). The determination coefficient (r^2) of the multiple regression equation was significant (0.19). This suggests that the higher the number in the CS-30 test, the greater the occlusal force.

As the majority of subjects used partial dentures, and it was difficult to clearly differentiate between natural and artificial teeth, comparison between them was not performed in the present study.

DISCUSSION

The present study examined the significance of measuring the occlusal force of elderly females living in the community in relation to grip force, strength of the quadriceps, sit-ups, length of forward bending in a sitting position, single leg standing time, walking speed, walking time of the 10-meter obstacle course, CS-30, MMSE, and TMT scores. In this study, an occlusal force meter, GM10, was used to measure occlusal force. As this equipment is simple, small, and light, it can easily be used in clinical settings, and it has been used to measure the occlusal force of the elderly in many studies. Significant correlations were noted between the occlusal force and all measurements, except that of the forward bending test in a sitting position. According to the results of stepwise regression analysis, a greater occlusal force is associated with a higher number of performances in the CS-30 test.

The occlusal force of elderly females (the subjects of this study) correlated with their physical (walking ability and balance as well as the strengths of the arm and leg muscles), cognitive, and attention functions. Previous studies designed, to examine the influence of the occlusal force of the elderly (which is one of the food-intake functions) on their physical activities, have suggested that if the occlusal force is maintained in the elderly, their grip force, balance function, and ADL are also maintained, since the occlusal force is closely associated with physical functions[16]. According to studies of the H-reflex of the soleus muscle (an index of excitation of the spinal motor neurons), when subjects attempt to maintain balance in response to a disturbance, they clench their teeth[17, 18]. Aoki et al.[4] suggested that healthy adults with a strong occlusal force were able to process information in a short time, a hypothesis which is supported by the results of the present study.

Multiple regression analysis was conducted with the occlusal force as the objective variable, and a significant par-

tial correlation was found with the the CS-30. The CS-30 is a simple test which assesses the leg muscles of the elderly, and its reliability and validity have been established. As a reduction in the strength of the leg muscles is related to decreases in walking speed rate, balance ability, and daily life functions, it may be a factor associated with falls in daily life[19–21]. One study also suggested that the leg muscles are an important factor in the prediction of changes in the physical functions of the elderly[22]. Since the result of the CS-30 test is associated with the strength of the leg muscles, walking ability, standing-balance ability, and ADL, occlusal force is related to complex functions, by the results of the present study.

Although the present study did not identify the mean number of teeth of the elderly, a survey of the number of teeth and assessment of functions related to the occlusal force and efficiency, conducted by Maeda et al.[23], suggested that when people in their 40s and 50s understood the importance of maintaining their teeth and occlusal force and oral care from an early stage, they could maintain their QOL. Maeda et al. also suggested that an appropriate level of occlusal force is an important factor related to maintenance of body balance control. Therefore, to implement nursing care prevention for the elderly and to help them to continue to lead a healthy and independent life, it is necessary to provide them with comprehensive support, including dietary and exercise support, while taking into consideration the maintenance of occlusal force. However, the present study only examined healthy elderly females who were able to lead an independent daily life, and the results do not necessarily apply to the elderly who are male, frail, or in need of nursing care. To generalize the results, further studies of such subjects should be conducted.

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