Relationships among Masticatory Ability, Handgrip Strength, and Dietary Habits in Subjects Ranging in Age from Children to Elderlies

Yoko YOSHINO¹, Asako KAMIYAMA², Nobuyuki HARIKAE³, and Masashige SUZUKI⁴

Abstract

Objectives: We examined the relationships among masticatory ability, physical fitness, and dietary habits of the general public.

Methods: Masticatory ability using a chewing-gum method and handgrip strength measurements were obtained from 2,104 subjects aged 3 to 97 years old (767 males, 1,337 females). We then analyzed the relationships among masticatory ability, handgrip strength (as an index of physical fitness), and dietary habits with the latter data collected from a questionnaire regarding diet over 3 days collected from 57 of the subjects (21 males, 36 females).

Results: Masticatory ability was significantly correlated to handgrip strength (male: \( r = 0.492, p < 0.001 \), female: \( r = 0.481, p < 0.001 \)), and a significant difference was found between subjects who exercised habitually and those who did not exercise habitually (male: \( p < 0.05 \), female: \( p < 0.001 \), \( \chi^2 \)-test). From the self-reported dietary questionnaire, the numbers of different foods ingested per day were totalled and percentage of hard foods was calculated. We found a slight correlation between the number of different foods ingested during breakfast (\( r = 0.364, p < 0.05 \)) and masticatory ability whereas there was no relationship between masticatory ability and the percentage of hard foods consumed.

Conclusion: Our results suggest that the correlation between masticatory ability and physical fitness is higher than between masticatory ability and dietary habits, and we concluded that exercise is very important to maintain or improve masticatory ability. It was also suggested that it is more important to ingest a variety of foods, especially during breakfast, rather than only hard food.

Key words: Masticatory ability, Handgrip strength, Dietary habit, Number of different foods during breakfast

Introduction

Mastication means physiological process that was carried out at the oral cavity for making bolus until be easy to swallow after food intake (Nomura, 1998). The food was crushed, mixed with saliva, grinded softly, made food bolus. In other words, mastication process is cooperated skillfully with many organs that are teeth, periodontium, masticatory muscles, jaw joint and tongue. Recently, it has led to bring that

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high performance of masticatory ability has a positive effect for the whole body (Tomida et al, 2002).

Further, it has been proposed that jaw growth becomes active (Poikela et al, 1997) and a larger area of the brain region becomes activated by mastication (Onozuka et al, 2002). In addition, mastication is considered to activate the cell objects in the histamine neurons in the hypothalamus and also plays important roles in appetite control, peripheral fat organization, and in raising energy consumption by the body (Masaki et al, 2001).

For chewing hard food, a strong biting force is required and, to completely chew food, coordinated movements among the muscles of the tongue, check, mouth, and labium are necessary. In order for these muscles to work correctly, it is thought that overall physical fitness is important.

It has also been shown that a high level of masticatory ability is needed to achieve high nutritional utilization of ingested foods, and that such an ability increases during infancy and adolescence, while it decreases with age. Recently, it was said that many Japanese tend to eat soft food, and it has been suggested that the development of masticatory ability is insufficient as a result (Yanagisawa, 2000), while other reports have recommended that hard food be consumed rather than soft food and that chewing well is important.

It has long been recognized that guidance regarding nutritional deficiency and maintaining a high masticatory ability are needed to avoid infirmities and a bedridden condition in the elderly. Further, dysmasesis and dysphagia occasionally arise with a decline in oral function or increase in dental disorders. To prevent elderly patients from becoming bedridden, it is necessary to maintain physical fitness, and handgrip training and arm strength exercises have been recommended, as it has been suggested that the muscle mass and activity required for mastication may be affected by both dietary and exercise habits.

It seems that handgrip strength is used in parameter grasp loss of bodily strength and nutritional status on the disorder that may cause variation of the physical component (Abe et al, 2002). And further, it is suitable for elderly people to survey the body function easily.

Several investigations have been conducted regarding the effects of masticatory ability on systemic health and several reports of the effects of different kinds of foods have also been presented. In one study, biting force in athletes was found to be significantly higher than in non-athletes, while there were significant positive correlations between biting force and handgrip strength and biting force and back strength in athletes (Iwasaki et al, 1994). In another study, a relationship was found between handgrip strength and vital capacity, as well as back strength and masticatory ability, in elderly subjects (Teraoka et al, 1997). In other reports, it has become well accepted that masticatory ability is significantly correlated with a large number of existing natural teeth (Nomura, 1998) and dentition status is considered to be closely related to physical disability, mental impairment, and mortality in elderly people (Shimazaki et al, 2001). Further, masticatory muscle activity is enhanced with the ingestion of hard foods (Miwa et al, 2001) and a lean body mass was shown to be related to masticatory ability, but not dietary habits, in college students (Kuwano et al, 1998).

In spite of the variety of findings referred to above, there have been few studies of masticatory ability covering a wide subject age range. Previously, we reported that there were relationships between masticatory ability and physical characteristics, as well as exercise habits and heredity factors (Yoshino et al,
In the present study, additionally we analyzed masticatory ability in subjects ranging in age from children to elderly in an attempt to clarify the relationships among masticatory ability, handgrip strength (as an index of physical fitness), and dietary habits.

**Materials and Methods**

1. **Subjects**

This survey was conducted by the spirit of Helsinki medical oath and we explained that there were no adverse effects on oral cavity. And we measured masticatory ability and handgrip strength to subjects who were agreed with the content of this plan. This survey was mindful of the protection of private information, and followed ethical principle of research and studies. The composition of the subjects was showed Table 1.

Masticatory ability and handgrip strength were determined in 2,104 subjects aged 3 to 97 years old. We previously reported other findings for this study population (Yoshino et al, 2003). For the present study, we determined masticatory efficiency using a chewing-gum method (Hada et al, 1977), and handgrip strength in both hands, as an index of physical fitness, using a dynamometer.

2. **Questionnaire**

We utilized a questionnaire that asked about exercise habits and frequency, as well as types of sports participated in and sport activity background during school age. According to the exercise allowances for health promotion, exercise that continued 20 minutes or more per day was recommended. Therefore we decided to exercise habit in the case of doing constantly for a month and for 20 minutes per day. In addition, self-reported dietary records for a consecutive 3 days were acquired from 57 of the subjects (21 males, 36 females). As for dietary habit we asked for filling out ingredients ingested during breakfast, lunch and supper for three days and send by mail at a later date. We did not ask for filling the weight for the reason that they have not kitchen scale at one’s respective homes and we could not grasp full measure. From those dietary record results, we ranked every ingested food per day by each subject based on the food classification table (Yanagisawa et al, 1989). We ranked soft food as 1 or 2, firm food from 3 to 6, and hard food from 7 to 10, based on the amount of energy required to chew them. For example, silken tofu (83 μV. sec) and potatoes (186 μV. sec) were regarded as soft, bread (451 μV. sec), Japanese noodles (723 μV. sec), rice (832 μV. sec), and spaghetti (1,109 μV. sec) were firm, and fresh slices of raw calamari (1,315 μV. sec), deep-fried tofu (1,490 μV. sec), pork (1,769 μV. sec), and dried calamari (2,542 μV. sec) were firm. Then we calculating the number determined whether the food was soft, firm, or hard and then we calculated the percentage of hard foods among all foods consumed each day. In addition, we determined the number of different types of foods ingested during breakfast, lunch, and dinner.

3. **Statistical analysis**

For comparisons of exercise habits and masticatory ability, a chi-square analysis was used. Significance was considered for results below the 5% level.

<table>
<thead>
<tr>
<th>Age (year)</th>
<th>Male n</th>
<th>Female n</th>
<th>Total n</th>
</tr>
</thead>
<tbody>
<tr>
<td>3~6</td>
<td>79</td>
<td>106</td>
<td>185</td>
</tr>
<tr>
<td>7~12</td>
<td>173</td>
<td>257</td>
<td>430</td>
</tr>
<tr>
<td>13~18</td>
<td>27</td>
<td>53</td>
<td>80</td>
</tr>
<tr>
<td>19~29</td>
<td>45</td>
<td>107</td>
<td>152</td>
</tr>
<tr>
<td>30~39</td>
<td>138</td>
<td>277</td>
<td>415</td>
</tr>
<tr>
<td>40~49</td>
<td>90</td>
<td>125</td>
<td>215</td>
</tr>
<tr>
<td>50~59</td>
<td>53</td>
<td>109</td>
<td>162</td>
</tr>
<tr>
<td>60~69</td>
<td>92</td>
<td>175</td>
<td>267</td>
</tr>
<tr>
<td>70~79</td>
<td>60</td>
<td>110</td>
<td>170</td>
</tr>
<tr>
<td>80~</td>
<td>10</td>
<td>18</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>767</td>
<td>1,337</td>
<td>2,104</td>
</tr>
</tbody>
</table>
Results
1. Masticatory ability and handgrip strength

We investigated masticatory ability and handgrip strength in 2,103 subjects aged from children to elderly (Fig. 1-a, 1-b). Masticatory ability is affected by eruption of the tooth. In contrast exercise and dietary habit are affected by factor from life stage. As for age composition we classified childhood, later childhood, early adulthood, classified every ten years and over thirty years old. Masticatory ability was found to increase between infancy to adolescence and reached a peak in subjects in their 40’s. The masticatory ability of males was maintained at a higher level until the subjects reached their 70’s, whereas it began to decrease in females in their late 60’s.

Handgrip strength also increased from infancy to adolescence and reached a peak in subjects in their 30’s, and then decreased gradually thereafter. The peak handgrip strength was 49.1kg in males and 29.1kg in females, and was reduced to 31kg in males and 18.1kg in females over 80 years old. Although peak masticatory ability was observed in subjects in their 40’s, peak handgrip strength was observed in subjects in their 30’s.

We also investigated the relationships between masticatory ability, handgrip strength (as an index of physical fitness), and exercise habits. Our results showed that masticatory ability was significantly correlated with handgrip strength in both males and females (Fig. 2, male: $r=0.492, p<0.001$; female: $r=0.481, p<0.001$), though the correlation coefficient for males was slightly higher.

2. Masticatory ability and physical fitness

Next, we examined the relationship between masticatory ability and exercise habits (including sport participation background). To clarify the influence of exercise habits, the findings were classified by 2 factors, exercise habits and masticatory ability, which were averaged by age group (Fig. 3, Table 2-a, 2-b). We found
that exercise is one of the factors to increase masticatory ability in both (female \( p < 0.001 \)) and (male \( p < 0.05 \)) using chi-squared test.

3. Masticatory ability and dietary habits

To understand the influence of dietary habits on masticatory ability, we analyzed the self-reported dietary records of 57 subjects to determine the relationship between mastication ability and dietary habits. Table 3 shows the average percentage of hard foods consumed per day by the subjects. As for hardness of the ingested food, firm was consumed most often (male: 58.6%, female: 58.6%) and hard the least often (male: 10.1%, female: 8.1%).

There were no correlations found between the hardness of food and masticatory ability (Fig. 4-a), and only a slight correlation between the number of different foods consumed per day and masticatory ability \( r = 0.266, p < 0.05 \). The total number of different foods ingested on each day was separated into that consumed during breakfast (Fig. 4-b), lunch (Fig. 4-c), and dinner (Fig. 4-d). A significant correlation was found for breakfast \( r = 0.364, p < 0.05 \), while none of the other parameters showed a correlation.

### Discussion

To clarify the relationships among masticatory ability, physical fitness, and dietary habits, we studied subjects ranging in age from children to elderly. The presence, number, and distribution of natural teeth are known to be related to the ability to eat certain foods, and also had an effect the intake of nutrients and 2 biochemical measures of nutritional status (Sheiman et al, 2001). The loss of teeth reduces masticatory capacity, and subsequently

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**Table 2** Exercise habits and masticatory ability

<table>
<thead>
<tr>
<th>Exercise habit</th>
<th>Masticatory ability</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Yes</td>
<td>330</td>
<td>251</td>
</tr>
<tr>
<td>No</td>
<td>160</td>
<td>178</td>
</tr>
<tr>
<td>Total</td>
<td>490</td>
<td>429</td>
</tr>
</tbody>
</table>

i. The subjects were categorized into high or low masticatory ability groups, by comparing the results with the average value for each age group.

ii. There were significant correlations between exercise habits and masticatory ability, as shown by the results of a chi-squared test (female; \( p < 0.001 \), male; \( p < 0.05 \)).

**Table 3** The percentage of hard foods consumed per day

<table>
<thead>
<tr>
<th></th>
<th>Soft</th>
<th>Medium</th>
<th>Hard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>31.5</td>
<td>58.6</td>
<td>10.1</td>
</tr>
<tr>
<td>Female</td>
<td>33.1</td>
<td>58.6</td>
<td>8.1</td>
</tr>
</tbody>
</table>
Relationships among Masticatory Ability and Handgrip Strength

Fig. 4 Food habits and masticatory ability
Relationships between ingestion of hard food each day and masticatory ability (a-a), number of foods consumed during breakfast and masticatory ability (a-b, p < 0.05), number of foods consumed during lunch and masticatory ability (a-c), and number of foods consumed during dinner and masticatory ability (a-d).
Masticatory ability represented the numerical value which subtracted individual data from the means of corresponded age.

Influences the selection of food and nutritional status. Thus, it is considered important for elderly people to preserve high a level of masticatory ability, while maintaining handgrip strength and a good nutritional status.

Previous studies of the relationships between masticatory ability and health have been reported, though most were investigations regarding maximum biting force. There are also several reports of the relationship between the ability to eat certain foods and systemic health in elderly people that were conducted with a self-assessment questionnaire. In the present study, we used a chewing-gum method to determine masticatory ability, as it enabled the examination of a wide range of subject ages.

Although masticatory ability was found to be maintained at a high level in male subjects into their 70's, it began to decrease in females in their late 60's. It has been reported that if there are at least 20 teeth present, few problems are encountered with food choice, however, the average number of residual teeth in people 65 years old or greater is less than 20. Most previous studies were restricted to young males or the elderly, whereas we determined masticatory ability in 2,104 subjects ranging in age from children to elderly.

The test of handgrip strength is used in Japan as a measurement of physical fitness for subjects aged 65 and older, from the point of view that muscle atrophy and hypofunction with aging can accelerate the systemic degrading of physical fitness. Thus, since handgrip strength is an important index that shows the physical fitness of elderly people, we employed it in the present study. Handgrip correlated with masticatory ability and biting force, and is important indicator easily to make a guess as to overall health in elderly.
In the present subjects, peak masticatory ability was found in those in their 40's, while handgrip strength peaked in subjects in their 30's.

According to a nation-wide investigation of handgrip strength in Japan, the peak was 49.6kg in males and 30.5kg in females in their 30's (Ohtsuki, 2001) which correlate with the present results. Further, the present results found handgrip strength of 20kg in female subjects over 80 years old. Correlations between handgrip strength and degree of independence have been reported and, when it is less than 13kg, the possibility exists of lapsing into institutionalized care for elderly people (Suzuki, 2000). It has found that if people exercises with dumbbells with 300g, handgrip strength increases at 2 months and maintained forever after. People exercises with dumbbells continuously increase handgrip, but people do not decrease handgrip in a short time. It seems that handgrip strength is used in parameter grasp loss of bodily strength and nutritional status on the disorder that may cause variation of the physical component (Abe et al, 2002). It has indicated that handgrip strength is related to falling and happiness in elderly people. If handgrip strength is significant decrease, disturbance is easy to occur in the future (Simona et al, 1999).

Therefore in elderly people it is speculated that handgrip strength is one of important parameter to maintain quality of life.

In the present study, masticatory ability was significantly correlated with handgrip strength, which agrees with several previous studies. Further, biting force was significantly correlated to handgrip strength and back strength in a previous study of young subjects (Iwasaki et al, 1994). It has also been reported that masticatory ability, handgrip strength, and sense of equilibrium were highly correlated in elderly subjects (Teraoka et al, 1997). These findings suggest that preservation of handgrip strength is important for maintaining masticatory ability. The present results also revealed that masticatory ability was significantly higher in both males and females who exercised habitually, which also agree with those obtained by Kuwano et al. It is shown that biting force is correlated with habitual physical activity and lean body mass (LBM), but not to dietary habits. Exercise training stimulates each organ in the body and increases body function. Physical inactivity raises muscle atrophy and reduces mineral of bone, cardiac output, maximal oxygen uptake and physical fitness (Kishi et al, 1999). Exercise habit is merit further research in terms of not only the variety of effect to health but also healthy habit actively.

Thus, we speculated that habitual exercise is effective for the preservation of masticatory ability.

Masticatory muscular activity is known to be affected by food texture (Yanagisawa et al, 1989), though it may only reflect personal masticatory rhythm (Takahashi et al, 1989). With the shift toward preference for soft food in recent years in Japan, it is becoming more difficult to select hard foods, as most food consumed by Japanese is processed soft food.

For the present study, we rated the hardness of food eaten by the subjects each day, based on the table of mastication muscle activities for 144 food items presented by Yanagisawa et al. Those foods not listed in the table were scored on the basis of similar foods. The average percentage of hard foods consumed, such as a hard small fish, dried fish, pickles, and nuts, was only 10% (male: 10.1%, female: 8.1%), thus we concluded that the mastication activity was low. As a result, we considered that a relationship exists between the ingestion of hard foods and masticatory ability. Further, the total number of types of food ingested per day and number ingested at breakfast were significantly
Relationships among Masticatory Ability and Handgrip Strength

related to masticatory ability, whereas none of the other parameters showed correlations. No such relationship was found for lunch, as the results varied widely depending on lifestyle, such as dining out, eating a prepared school lunch, and eating a lunch brought from home. Most of the present subjects ate a dinner that was well balanced in nutrition. As for breakfast, some subjects ate various numbers of foods on different days, while some tended to have simple meals, such as bread and coffee.

Although many reports have advised the selection of hard food, we found no relationship between hard food and masticatory ability, whereas the number of foods ingested had a significant relationship to masticatory ability. Further, though most of our subjects ate various foods at each meal, individual differences were large for breakfast. These findings suggest that it is more important to ingest a large number of foods, especially at breakfast, rather than consume only hard food, as our subjects consumed mostly soft foods. Therefore, the number of different types of foods consumed during breakfast may be significantly related to masticatory ability.

In the present study, we found that both nutritional status and daily exercise had effects to maintain masticatory ability. Chewing ability in aged patients is important and, if elderly people can eat healthily by chewing, their food choices may be expanded, which is important for quality of life. Therefore, to heighten masticatory ability, it is suggested that daily exercise be undertaken by people of all ages.

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References
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咀嚼力と握力および食習慣との関係
—幼児から高齢者までの調査から—

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抄 録：咀嚼力が基礎体力、ならびに食習慣とどのような関係があるかを調べることを目的とした。調査対象者は女性1,337名、男性767名の計2,104名であり、年齢は3〜97歳であった。咀嚼力は、チェーインガム法による糖溶出量を指標とした。咀嚼力と基礎体力の指標の一つである握力との関連を調べた。また、男性21名、女性36名の計57名による3日間の食物摂取状況調査により、咀嚼力と食習慣の関連を調べた。

咀嚼力と握力との関係では有意な相関性が認められた（男性：r=0.492, p<0.001、女性：r=0.481, p<0.001）。また、咀嚼力と運動習慣の有無との関係を調べたところ、運動習慣のある人は、人に比べて有意に咀嚼力が高かった（男性：p=0.05、女性：p=0.001）。

食習慣との関係では、3日間の食物摂取状況調査から朝食、昼食、夕食の各々における摂取食品数と1日の総食品数を調べた。また、1日に摂取した食品中に占める硬い食品の摂取割合を調べ、これらが咀嚼力とのどのように関係しているかを検討した。その結果、朝食の食品数と咀嚼力の間には弱いながらも相関が認められた（r=0.364, p<0.05）が、昼食と夕食との間には関連性がみられなかった。また、硬い食品の摂取割合と咀嚼力の間には関連性がみられなかった。

これらの結果から、咀嚼力は食習慣よりも基礎体力や運動習慣のほうが相関性が高いことがわかった。したがって、今後は咀嚼力の向上や改善には運動指導をも取り入れる必要性があるのではないかと考えられる。また、これまでに硬い食品を摂取することが強調されてきたが、今回の調査により朝食の食品数と正の相関性が認められたことから、こうした要素も重要であることが示唆された。

キーワード：咀嚼力、握力、食習慣、朝食の食品数