Change in Autonomic Nervous Activity during Ingestion of Soft Food in Older Nursing Home Residents

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Abstract

The deterioration in masticatory function often seen in older adults rules out the consumption of hard foods, while a common decline in autonomic nervous response often observed in older adults may result in maladjustment to environmental stresses. The purpose of this study was to investigate whether autonomic nervous activity in older adults increased during the mastication of soft foods compared to at rest. The participants comprised 9 volunteer nursing home residents aged 78 to 100 years. All consumed soft rice as a grain dish and coarsely chopped food as side dishes. The coefficient of variation of R-R intervals (CVRR) and high-frequency (HF) power on electrocardiograph (ECG) served as indices of parasympathetic nervous activity, while the low-frequency (LF)/HF ratio served as an index of sympathetic nervous activity. Total power, reflecting the level of autonomic nervous activity, was also measured. We measured autonomic nervous activity while nursing home residents were eating lunch. HF was 3,457.4 ± 3,037.5 ms$^2$ at rest and 4,085.1 ± 3,697.7 ms$^2$ during mastication. The CVRR was 26.8 ± 16.9% at rest and 26.1 ± 16.1% during mastication. No significant difference was observed in HF or CVRR. On the other hand, the LF/HF ratio was 0.77 ± 0.24 ms$^2$ at rest and 31.0 ± 3.77 ms$^2$ during mastication (p = 0.011). A significant difference was observed in the LF/HF ratio between the resting and masticating conditions. Total power was 6,244.1 ± 5,752.5 ms$^2$ at rest and 8,417.7 ± 7,266.4 ms$^2$ during mastication (p = 0.038). A significant difference was also observed in total power between resting and masticating conditions. These results suggest that mastication of soft foods stimulates autonomic nervous activity in older adults. In conclusion, autonomic nervous activity increased during chewing soft foods compared to that during the resting level in older adults.

Key words: Autonomic nervous response — Aging — Soft food — Heart rate variability — Mastication
Introduction

Human internal environmental homeostasis and adaptation to external environments are primarily controlled by the hypothalamus, which hosts the centers of the sympathetic and parasympathetic nerve systems. These nerves regulate body temperature, the biological clock, awakening, sleeping, and eating, as well as the endocrine system. Therefore, autonomic nervous hypofunction reduces internal environmental homeostasis and adaptability to external environments. One study reported that autonomic nervous function can be altered by a number of factors, including diabetes mellitus, Parkinson’s disease, and other nerve diseases such as spinocerebellar degeneration; it also showed a decrease with physiological aging.

We previously noted that the level of resting autonomic nervous activity was lower in the elderly than that in young individuals, and that autonomic nervous activity in the elderly increased when chewing soft gum, which resembled soft food, when compared to at rest. However, gum chewing differs from masticatory movement during meals; therefore, the influence of diet on autonomic nervous activity in elderly persons remains to be clarified.

The ability to masticate and swallow deteriorates in advanced age, making it difficult to eat a standard diet. Therefore, it becomes necessary to adjust the form of diet in accordance with the degree of hypofunction. Dietary forms vary, from those that do not require mastication, such as pastes and blended food, to forms that are softer than the standard diet, but require mastication/trituration. If compressing or chewing soft food increases autonomic nervous activity, then ingestion of such may be of significant benefit, even in persons who are unable to eat a standard diet. Older adults who take soft foods are considered to have little stimulation to autonomic nervous system in their daily living. Therefore, it is a clinical significance of the present study that declining autonomic nervous activity of older adults increase by ingesting soft foods.

The purpose of this study was to investigate change in autonomic nervous activity in the elderly during ingestion of soft food in comparison to that at rest.

Materials and Methods

1. Participants

All the participants enrolled in this study were residents of a nursing home in Edogawabashi, Tokyo, Japan. To be eligible for inclusion in the study, all had to be capable of taking meals unassisted. All were provided with both soft rice, as a grain dish, and coarsely chopped meal as a side dish, for which the following were available: 4 types of grain dish (regular, soft, gruel, or paste); and 5 forms of side dish [regular sized, one-bite sized (2–3 cm cut), coarsely chopped (1 cm cut), finely chopped (0.5 cm cut), or blended] (Table 1).

The exclusion criteria were as follows: severe diabetes mellitus; asthma; cardiovascular disease with uncontrolled hypertension; use of medication with possible effects on the autonomic nervous system, such as anti-histamines; Parkinson’s disease; and spinocerebellar degeneration.

A total of 9 residents were enrolled based on the above criteria (mean age: 88 ± 7 years; 3 males, 6 females).

2. Evaluation of autonomic nervous activity

Spectrum analysis of heart rate variability (HRV) allowed non-invasive, simultaneous, and real-time evaluation of sympathetic and parasympathetic nervous activity. The coefficient of variation of R-R intervals (CVRR), low-frequency (LF) power, high-frequency (HF) power, and LF/HF ratio were determined from spectral analysis of evidence from electrocardiogram (FlexComp, Thought Technology Ltd, Montreal, Canada). Measurement was performed using BioGraph Infiniti software (Thought Technology Ltd, Montreal, Canada).

The frequency domain measures of HRV are shown in Table 2. A CVRR of 100 heart
beats and HF power were determined as indicators of parasympathetic nervous activity. The HF power is considered to be an index of breathing-related parasympathetic nervous activity. Because a respiration rate of lower than 0.15 Hz markedly affects HRV\(^\text{14}\), this study was performed after confirming a respiration rate of above 0.15 Hz in all participants. The LF/HF ratio is the ratio between the power of LF and HF bands, and indicates sympathetic nervous activity. The total power mainly reflects the level of overall autonomic activity.

Electrocardiograms at rest and during eating lunch were obtained by attaching a digital pulse-wave measuring device to the second finger of each participant’s non-dominant hand (Figs. 1, 2).

### 3. Statistical analysis

The statistical analysis was performed using the Wilcoxon signed-rank test to compare autonomic nervous activity at rest and during mastication. The data were presented as the mean $\pm$ SD. Differences were considered significant at $\alpha=0.05$. Statistical software (SPSS version 22; IBM, Chicago, IL, USA) was used for the analysis.

This study was approved by the Ethics Committee of Tokyo Dental College (approval no. 683).

### Results

The HF power, an index of parasympathetic nerve activity, was 3,457.4 $\pm$ 3,037.5 ms\(^2\) at rest and 4,085.1 $\pm$ 3,697.7 ms\(^2\) during chewing (Fig. 3). The CVRR was 26.8 $\pm$ 16.9\% at rest.

### Table 1

**Form of food offered in nursing home**

| Grain dish | Side dish |
|------------|-----------|
| Class      | Prepared size [cm] |
| Rice: Water |            |
| regular    | regular sized |
| soft*      | one-bite sized 2–3 |
| gruel      | coarsely chopped** 1 |
| paste      | finely chopped 0.5 |
|            | blended |

Grain dish and side dishes were selected from these classes of food for each individual. Study participants comprised those selecting soft rice (*) as grain dish and coarsely chopped side dishes (**).

### Table 2

**Frequency domain measures of HRV**

| Variable       | Unit     | Description                                      | Frequency range |
|----------------|----------|--------------------------------------------------|-----------------|
| CVRR           | %        | co-variation of RR interval of 100 heart beats   |                 |
| LF power       | ms\(^2\) | power in low frequency range                     | 0.04–0.15 Hz    |
| HF power       | ms\(^2\) | power in high frequency range                    | 0.15–0.4 Hz     |
| LF/HF ratio    |          | ratio LF [ms\(^2\)]/HF [ms\(^2\)]                |                 |
| total power    | ms\(^2\) | the variance of NN intervals                      | 0–0.4 Hz        |

CVRR: coefficient of variation of R-R intervals, LF: low frequency, HF: high frequency
and 26.1 ± 16.1% during chewing (Fig. 4). No significant differences were observed in either index between the values at rest and those during chewing. On the other hand, the LF/HF ratio, an index of sympathetic nerve activity, was 0.77 ± 0.24 ms² at rest and 3.1 ± 3.77 ms² during chewing, demonstrating a significant difference (p = 0.011) (Fig. 5). Furthermore, total power, an index of autonomic nerve activity, was 6,244.1 ± 5,752.5 ms² at rest and 8,417.7 ± 7,266.4 ms² during chewing, which was also significantly different (p = 0.038) (Fig. 6).

**Discussion**

Many older adults eat soft food due to masticatory hypofunction or dysphagia. Several studies have investigated mastication in the elderly. It was found that oral muscle weakness in such individuals had reduced active muscle mass, decreasing mastication efficiency, and diminishing tongue motor function, and it was suggested that this might increase the number of chewing cycles or prolong the chewing time per session of chewing. Therefore, meals for the elderly often comprise cooked soft and/or chopped food. With respect to the influence of mastication on autonomic nervous activity, previous studies indicated that autonomic nervous activity was enhanced upon chewing hard food, and that the parasympathetic nerves were more markedly activated by chewing food with a good taste/smell. It was reported that masticatory muscle activity and stimuli, such as dietary taste/smell, comprised an autonomic nerve feedback system. However, these studies investigated the influence of hardness or the taste of chewing gum on the autonomic nervous system. To our knowledge, however, no study to date has investigated change in autonomic nervous activity during the consumption of soft food. The purpose of the present study, therefore, was to investigate change in autonomic nervous activity...
activity in elderly individuals during consumption of soft food requiring mastication.

In the nursing home investigated here, physicians, dentists, and speech-language-hearing therapists determined the form of food for main and side dishes in accordance with individual masticatory function. Several studies indicated that the provision of meals with the appropriate form of food improved the nutritional state and reduced the nursing burden. Ogami et al. investigated associations among tongue-coating status, number of oral bacteria, food texture of side dishes, and care level, and reported that the tongue-coating status in older people requiring nursing care was affected by the form of food provided as side dishes. These findings suggest the necessity of selecting an adequate form of food for elderly individuals.

Autonomic nervous activity is usually determined by HRV analysis based on evidence from ECG. It is difficult, however, to obtain such data during active consumption of food. Therefore, in this study, autonomic nervous activity was determined by performing the HRV analysis using digital pulse waves. A digital pulse-wave meter was attached to the second finger of each participant’s non-dominant hand, after which they were instructed to eat a routine meal. This method does suffer

Fig. 3 Parasympathetic nervous activity by HF power Wilcoxon signed-rank test. HF: high frequency, NS: no significance

Fig. 4 Parasympathetic nervous activity by CVRR Wilcoxon signed-rank test. CVRR: coefficient of variation of R-R intervals, NS: no significance

Fig. 5 Sympathetic nervous activity by LF/HF ratio Wilcoxon signed-rank test. LF: low frequency, HF: high frequency, *: p<0.05

Fig. 6 Overall autonomic nervous activity by total power Wilcoxon signed-rank test. *: p<0.05
from the drawback of the potential for noise to skew the readings, however. Therefore, our first step was to determine whether noise was a factor by comparing ECG measurements with those obtained with the digital pulse-wave meter and confirming no difference. Most studies assessing autonomic nervous activity employed chewing gum because it is easy to adjust the hardness or taste of chewing gum\textsuperscript{1,3,12}. However, change in autonomic nervous activity while chewing gum over an extended period may not be reflective or that occurring during the consumption of daily meals. Furthermore, chewing gum may adhere to dentures, and it is sometimes difficult to evaluate autonomic nervous activity in those wearing dentures when working with the elderly. Here, on the other hand, the effects of soft food on autonomic nervous activity was evaluated during the consumption of regular meals.

An earlier study by this group clarified some important points\textsuperscript{10}. In the elderly, the LF, HF, and total powers at rest were lower than those in young individuals, whereas no significant differences were observed in the LF/HF ratio or CVRR between the two groups. When the same elderly were instructed to chew soft chewing gum meant to replicate soft food, an increase was observed in the HF and total powers compared to at rest, but no significant differences in the LF/HF ratio or CVRR. These results revealed that parasympathetic and autonomic nerve activities were reduced at rest in the elderly, whereas chewing soft gum increased these activities. In the present study, the LF/HF ratio, an index of sympathetic nerve activity, and total power, which reflects autonomic nervous activity, were higher than that at rest when soft rice or chopped food were ingested, but there was no increase in the HF power. Our previous study measured autonomic nervous activity upon chewing taste-free gum for 5 minutes\textsuperscript{10}, whereas the participants in the present study were instructed to eat the type of food they would normally consume on a daily basis. As a result, a feedback system from the digestive tract or gastric mucosa\textsuperscript{7}, in addition to that from the masticatory muscles or oral cavity, may have contributed to the results differing from those in the previous study. Even when eating food that was not crushed, there was an increase in the total power, suggesting that mastication of soft food stimulates the autonomic nerves.

The results of this study demonstrated that autonomic nervous activity, especially sympathetic activity, increased with ingestion of soft food. Even when eating soft rice or chopped food that was not crushed or compressed, autonomic nervous activity was activated, suggesting the effects of masticatory movement.

**Conclusion**

Autonomic nervous activity in older adults increased while chewing soft foods compared with that at rest.

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**Conflict of Interest**

The authors declare no conflict of interest with regard to this study.

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