〈Regular Article〉

Effect of gummy film sheet for tongue training on swallowing-related muscles

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ABSTRACT **Background**: The aim of this pilot study was to examine the impact of tongue movement while using film sheets on swallowing-related muscles in healthy adults and explores whether gummy film sheets can serve as a swallowing training aid.

Methods: We applied a gummy film sheet to the hard palate and instructed participants to lick the sheet as if it were pressed against it with their tongue, anticipating that it would provide training effects similar to those of tongue-strengthening exercises. Surface electromyography of the suprahyoid muscles and tongue pressure were measured during the use of the film sheet in 50 healthy adults. The sheet was applied in four distinct ways, based on its positioning on the hard palate and the manner in which it was licked.

Results: The method in which the film sheet was applied to the anterior portion of the hard palate and licked with maximal effort resulted in the highest muscle activity in the suprahyoid muscles and the greatest tongue pressure.

Conclusion: These findings suggest that the gummy film sheet can serve as an effective swallowing exercise to strengthen the muscles involved in swallowing.

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Key words：Gummy film sheet, Tongue-strengthening exercises, Suprahyoid muscles, Tongue pressure

INTRODUCTION

As the prevention of frailty and sarcopenia becomes increasingly emphasized in response to the rapidly aging population, there is growing interest in the role of oral frailty and sarcopenia, particularly regarding the swallowing-related muscles in older adults. Muscle atrophy and weakness of the swallowing-related muscles are well-documented in

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aging, even in the absence of diseases such as stroke or neuromuscular disorders that typically cause dysphagia[1-3].

Among the swallowing-related muscles, the tongue plays a pivotal role in generating intraoral and intrapharyngeal pressure during swallowing and facilitating the bolus feeding movement. When the maximum tongue pressure falls below 20 kPa, dietary adjustments are recommended[4]. The suprahyoid muscles also contribute significantly to swallowing by moving the hyoid bone forward and upward, enabling epiglottis inversion and the opening of the upper esophageal sphincter during swallowing[5-7]. In healthy older adults, reduced tongue pressure and atrophy of the suprahyoid muscles have been associated with diminished swallowing function and nutritional status[8-10], highlighting the importance of early prevention.

Tongue-strengthening exercises (TSE) are isometric exercises in which the tongue is pressed against the hard palate or a tongue depressor. These exercises are known to increase tongue pressure and volume while also strengthening the suprahyoid muscles[10-15]. TSE has garnered attention as a feasible self-training method for older individuals at home. In response, specialized devices have been developed and made available for public use, with research supporting their efficacy[14, 16, 17].

In this study, we applied a gummy film sheet to the hard palate, designed to be pressed against the palate by licking with the tongue, which is expected to provide effects similar to those of TSE. However, the effects of swallowing exercises using film sheets remain unclear. This pilot study examines the impact of tongue movement while using film sheets on swallowing-related muscles in healthy adults and explores whether gummy film sheets can serve as a swallowing training aid.

PARTICIPANTS AND METHODS

Fifty healthy adults (21 women) with a mean age of 29.4 ± 10.2 years (range: 21-59 years) participated in the study after being informed of the study's purpose and providing written consent. Individuals with a history of dysphagia or pharyngolaryngeal or cervical diseases were excluded from participation.

We used a dissolvable gummy film sheet (Tantore Co., Ltd., Aichi, Japan) measuring 20 × 30 mm and approximately 150 μm thick. The sheet contains supplemental ingredients and flavors, such as yogurt and peach, embedded within the film. Although the sheet is dry, it reacts with the moisture in the oral cavity, allowing it to adhere securely to the hard

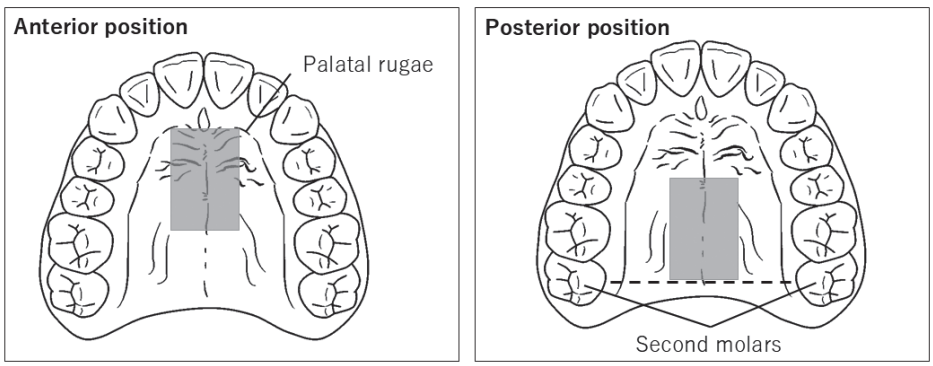

Fig. 1. Position of the film sheet.
Anterior position: The anterior part of the film sheet was positioned at the location of the palatal rugae.
Posterior position: The posterior part of the film sheet was positioned at the straight line connecting the right and left second molars.

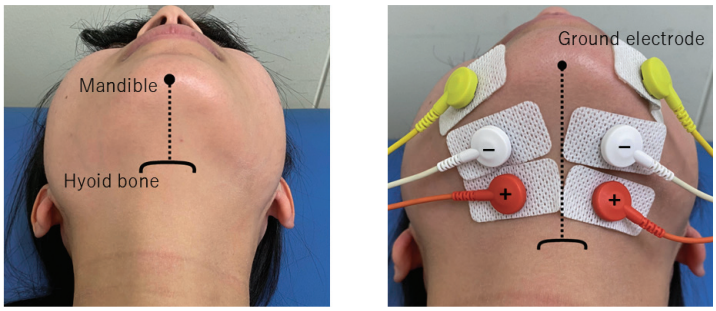

Fig. 2. Position of the surface electrode.
Surface electrodes were placed targeting the suprahyoid muscles, positioned midway between the mandible and hyoid bone, 20 mm to the left and right of the midline of the anterior neck, with an inter-electrode distance of 20 mm.

palate.

The long side of the rectangular film sheet was applied parallel to the sagittal plane of the participant's hard palate. The film sheet was positioned in two distinct locations (Fig. 1):

- **Anterior Position**: The anterior part of the film sheet was placed at the location of the palatal rugae.
- **Posterior Position**: The posterior part of the film sheet was placed along a straight line connecting the right and left second molars.

We instructed the participants to lick the film sheet in two different ways:

- **Normal Effort**: Participants were instructed to "lick the film sheet with normal force."
- **Maximum Effort**: Participants were instructed to "lick the film sheet with maximum force."

All participants performed four tasks, each corresponding to the placement of the film sheet and the licking effort:

- **Task 1**: Anterior position and normal effort
- **Task 2**: Posterior position and normal effort
- **Task 3**: Anterior position and maximum effort
- **Task 4**: Posterior position and maximum effort

The direction and speed of tongue movement were not specified, allowing for natural variation in individual tongue motion.

EXPERIMENTAL PROCEDURE

Initially, the forehead exercise for suprahyoid muscles (FESM, known as "Enge-Odeko-Taiso" in Japanese) was performed for approximately 5 s to measure the myoelectric signal during maximal voluntary contraction of the suprahyoid muscles. FESM is an isometric exercise designed to strengthen the suprahyoid muscles. It involves looking toward the navel as if the chin is pulled back with minimal neck motion while using a hand pressed against the forehead for resistance[18].

Subsequently, the four tasks (1-4) were performed in a randomized order using the gummy film sheet to measure tongue pressure and the surface electromyography (EMG) of the suprahyoid muscles. Randomization of tasks was carried out using the RAND function in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Each task lasted 12 s, with a minimum of a 1-min break between tasks to prevent fatigue.

Data Collection

First, the participant's submental skin was cleansed and degreased using alcohol wipes. Surface electrode pads (Erlode SMP-300; METS INC., Tokyo, Japan) were placed targeting the suprahyoid muscles, positioned midway between the mandible and the hyoid bone, 20 mm to the left and right

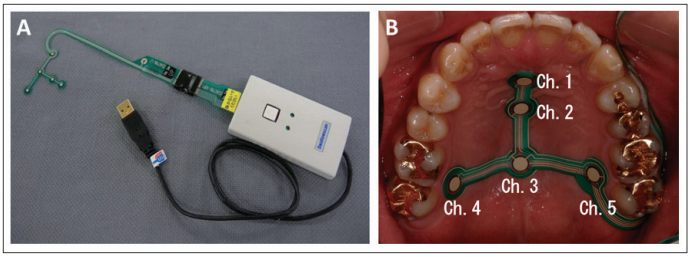

Fig. 3. The system for measuring tongue pressure.
A. Swallow scan (Nitta Corporation, Osaka, Japan).
B. Three measuring points (Ch.1-3) were positioned along the median line of the hard palate, with Ch.1 at the anterior-median region, Ch.2 at the mid-median region, and Ch.3 at the posterior-median region. Additionally, two sensors, Ch.4 and Ch.5, were placed in the posterior regions of the hard palate, on the right and left sides.

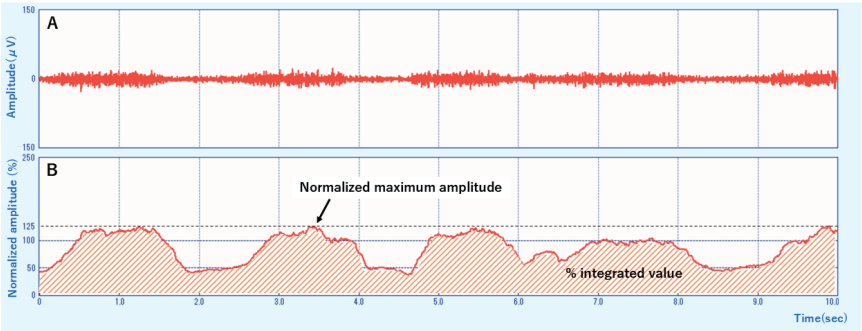

Fig. 4. A representative case of the surface electromyography (sEMG) of the suprahyoid muscles. Using dedicated software installed on a personal computer, myoelectric signals
(A) and normalized amplitude
(B) are recorded simultaneously. The normalized amplitude is calculated based on the maximum amplitude obtained during a pre-measured FESM. The normalized maximum amplitude is defined as the ratio of the maximum amplitude during a 10-s task measurement to the maximum amplitude during FESM (arrow). Additionally, the % integral value is calculated as the integral of the normalized amplitude over the 10-s period (shaded area).

of the midline of the anterior neck, with an inter-electrode distance of 20 mm. The ground electrode was attached to the mandible (Fig. 2). To ensure optimal contact with the skin, a thin film dressing was used to secure the surface electrodes. Surface electromyographic signals were recorded using an MWATCH device (Wada Aircraft Technology Co., Ltd., Aichi, Japan). The EMG signals were A/D converted at a sampling frequency of 1 kHz and transmitted via Bluetooth to a personal computer using dedicated software.

In addition, simultaneous tongue pressure measurements were performed on five randomly selected participants (three females aged 23-46). Tongue pressure was measured using a 0.1 mm thick T-shaped sensor sheet with five measuring points (Swallow-Scan; Nitta Corporation, Osaka, Japan). Channel 1 (Ch.1) was positioned 5 mm posterior to the incisive papilla (Fig. 3). A small, medium, or large sensor sheet was selected for each participant based on the size of the hard palate. The sensor sheet was attached directly to the palatal mucosa using a sheet-shaped denture adhesive (Touch Correct II; Shionogi & Co., Ltd., Osaka, Japan). A conductive ink embedded in the sensor sheet converted tongue pressure into electrical signals, which were recorded

on a personal computer in real time.

DATA ANALYSIS

The maximum amplitude of the full-wave rectified waveform of the myoelectric signal measured during the FESM was used as a reference to calculate the normalized amplitude for each of the four tasks. Each task, performed for 12 s, was analyzed over a 10-s period, excluding the first and last seconds.

For surface EMG, the normalized maximum amplitude during the 10-s measurement period (normalized maximum amplitude, %) and the integrated value over the same period (integrated value, %·sec) were calculated (Fig. 4). Tongue pressure was analyzed by determining the maximum tongue pressure recorded in each channel during the 10-s period (maximum tongue pressure, kPa) and the total integral value of tongue pressures across all channels (total tongue pressure integral value, kPa·sec).

This study was approved by the Research Ethics Committee of Kawasaki Medical School Hospital (approval no. 5186-01).

Statistics

The normalized maximum amplitude and percentage integral for each of the four tasks were analyzed using one-way analysis of variance (ANOVA), with Tukey's multiple comparisons performed when significant differences were observed. The significance level was set at 5%. Statistical analysis was not conducted for maximum tongue pressure and total tongue pressure integral values due to the small sample size, and trends were examined for each task. All statistical analyses were performed using IBM® SPSS Statistics (Version 22).

RESULTS

The normalized maximum amplitude of the suprahyoid muscles was significantly different according to the one-way ANOVA ($p < 0.000$). The highest normalized maximum amplitude was found in task 3 (anterior, maximum), which was significantly greater ($p < 0.000$) than both task 1 (anterior, normal) and task 2 (posterior, normal) ($p < 0.000$) (Fig. 5). The percentage integral value also showed significant differences in one-way ANOVA ($p < 0.000$). The largest percentage integral value

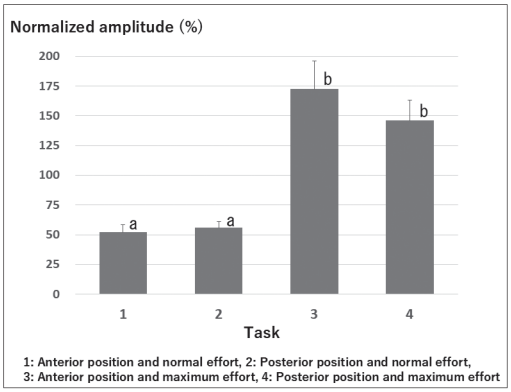

Fig. 5. Normalized amplitude of suprahyoid muscles.
One-way analysis of variance (ANOVA) showed significant differences in normalized maximum amplitude between the four tasks, as indicated by different letters. The normalized maximum amplitude for task 3 was significantly higher than that for tasks 1 and 2.

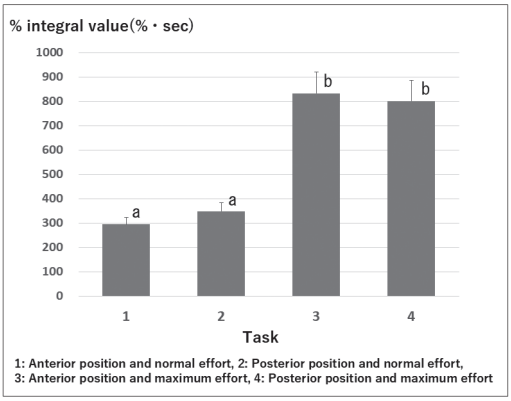

Fig. 6. The % integral value of the suprahyoid muscles.
One-way analysis of variance (ANOVA) showed significant differences in % integral values between the four tasks, as indicated by different letters. Specifically, the % integral value for task 3 was significantly higher than that for tasks 1 and 2.

Table 1. The maximum tongue pressure and total tongue pressure integral (median)

	Task	1	2	3	4
MTP (kPa)	Ch.1	6.82	5	35.46	19.09
	Ch.2	10.36	11.15	32.77	28.66
	Ch.3	0.2	6.06	3.85	31.15
	Ch.4	1.69	6.99	20.77	22.05
	Ch.5	2.06	6.54	31.36	20.19
Total tongue pressure integral (kPa・sec)		39.62	47.34	376.86	256.53

MTP: Maximum Tongue Pressure
Task 1: Anterior position and normal effort
Task 2: Posterior position and normal effort
Task 3: Anterior position and maximum effort
Task 4: Posterior position and maximum effort

was observed in task 3 (anterior, maximum), which was significantly larger ($p < 0.000$) than task 1 (anterior, normal) and task 2 (posterior, normal) ($p < 0.000$) (Fig. 6).

The maximum tongue pressure was highest in task 3 (anterior, maximum), with Ch1 (anterior hard palate) showing a mean of 35.46 (34.70, 49.49) kPa, followed by Ch2 (middle hard palate) with 32.77 (14.95, 34.23) kPa. These results indicate higher values in the anterior and central regions of the hard palate. The total tongue pressure integral value was highest for task 3 (anterior, maximum) at 376.86 (277.82, 401.64) kPa, followed by task 4 (posterior, maximum) at 256.53 (153.63, 327.93) kPa (Table 1).

DISCUSSION

TSE are isometric exercises in which the tongue is pressed against the hard palate or a tongue depressor. This training method has been shown to improve maximum tongue pressure, increase the muscle mass of the suprahyoid muscles, and enhance swallowing function[10–15]. This pilot study examines whether gummy film sheets can be used for swallowing exercises similar to TSE. The results showed that the task producing the greatest muscle activity in the suprahyoid muscles and the highest tongue pressure involved applying the film sheet to the anterior region of the hard palate and licking it with maximum effort. Using this method, the maximum tongue pressure during the use of the gummy film sheet was 35.46 kPa (anterior to the hard palate). Maximum tongue pressure in healthy adults (ages 20-59 years) has been reported to average 45 ± 10 kPa for men and 37 ± 9 kPa for women[3]. Additionally, a common TSE protocol recommends performing exercises at 60-80% of maximum tongue pressure[19]. The use of the gummy film sheet differs from TSE in that it involves licking the hard palate rather than pressing the tongue against it. Although this study did not directly compare the gummy film sheet method with TSE, the act of licking a film sheet attached to the hard palate may also generate sufficient tongue pressure.

Yano *et al.*[11] reported that 8 weeks of TSE in healthy adults resulted in improved tongue pressure and muscle hypertrophy of the geniohyoid muscle. In a study involving healthy older adult participants, researchers found that 8 weeks of TSE effectively improved tongue pressure and increased tongue volume, proving useful as a training method to prevent muscle atrophy in swallowing-related muscles in older adults[10]. Additionally, 27 healthy older adult participants (average age 84.5 years) who continued using the Peco Panda® (JMS Co., Ltd., Hiroshima, Japan), a self-training tool, for 8 weeks showed increased maximum tongue pressure and endurance. This study highlighted the usefulness of TSE as a self-training method for older individuals at home[14].

The gummy film sheet offers the advantage of an easy-to-understand training method, as it is simply licked to dissolve the film. Moreover, the flavor of the sheet stimulates the sense of taste, which may help maintain motivation for continued use. For these reasons, we believe that gummy film sheets could serve as an accessible method for older adults to perform swallowing exercises consistently.

LIMITATIONS

The mean age of the participants in this study was 29.4 years, with a tendency toward a younger age group. The tongue movement required to lick the hard palate may differ depending on the age of the participants, and future studies should compare older and younger groups. Additionally, the tongue pressure sensor sheet used in this study was limited to only five participants for tongue pressure measurement due to low stock, as its production has been discontinued. Due to the small sample size, it was difficult to perform statistical analysis on the tongue pressure results.

In the future, it is necessary to use gummy film sheets with older adult participants and conduct further research on their safety, continuity, and long-term effectiveness.

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