



Effects of Tongue-Strengthening Exercise on the Geniohyoid Muscle in Young Healthy Adults

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Abstract

The activities of the suprahyoid muscles have been reported to be induced by tongue muscle contraction. The purpose of this research was to investigate whether tongue-strengthening exercises using a device cause hypertrophy of the geniohyoid muscle in healthy adults. Seven healthy young adults (3 men and 4 women, 21.0 ± 1.3 years old) received 8-week tongue muscle training with the JMS Tongue Pressure Measuring Device. The participants were instructed to press the anterior tongue against the hard palate 30 times in each session, three sessions a day, and 3 days a week. The exercise intensity was set to 60% of maximum tongue pressure in the first week, and to 80% of maximum tongue pressure for the remaining period. The training effect was evaluated by measuring (1) maximum tongue pressure value with the JMS Tongue Pressure Measuring Device, and (2) the area at rest, shortening amount, and contraction ratio of the geniohyoid muscle using ultrasonic imaging. After the 8-week training program, the maximum tongue pressure increased significantly from 44.9 to 61.6 kPa. The area of the geniohyoid muscle at rest also increased significantly from 2.3 to 2.6 cm² after the program. There were no significant differences in the shortening amounts and the contraction ratios of the geniohyoid muscle between the values before and after the program. The tongue-strengthening exercise was useful to increase the muscle power of the geniohyoid, as well as the tongue muscles, in healthy young adults.

Keywords Tongue pressure · Exercise · Suprahyoid muscles · Ultrasound · Swallow · Deglutition · Deglutition disorders

Introduction

The suprahyoid muscles have been reported to play an extremely important role in swallowing. They move the hyoid bone forward and upward, and they contribute to

epiglottic inversion and wide opening of the esophageal orifice [1, 2]. The tongue muscles also play important roles in swallowing. Their roles are bolus retention in the oral cavity and bolus transport from the oral cavity to the pharynx

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[3–6]. The base of the tongue generates swallowing pressure within the pharynx [7, 8].

Swallowing function is known to decrease with aging. In particular, reduced laryngeal elevation and weakness in tongue muscle strength adversely affect swallowing functions in the oral and pharyngeal stages [9–11]. This functional decline is itself the state of sarcopenia or frailty, which is one of the causes of aspiration pneumonia and malnutrition [12–18]. Resistance training is necessary to prevent such functional decline [19–22]. The Shaker Exercise [23, 24] and tongue-strengthening exercises [20, 25–27] using several devices and tongue depressors have been most frequently chosen to prevent weakness in laryngeal elevation and tongue strength. There are few elderly people with only either laryngeal elevation or tongue muscle strength decreasing [11, 13, 14, 28, 29]. That is, they often have weakness of both muscles. In such cases, both the Shaker Exercise and tongue-strengthening exercises are necessary, but elderly people may become fatigued if both are performed at the same time. Complex training procedures may lead to a negative attitude towards training with them. Additionally, it is dangerous for patients with cervical spine diseases to perform the Shaker Exercise. Because the intensity of the Shaker Exercise, as one of the indirect swallowing exercises, is high, there are not as many people doing it as self-training [30]. Patients may be more likely to continue self-training at home if it must be simple, effective, and feasible in a short period of time.

Some previous studies reported relationships between tongue muscle contraction and activities of the suprahyoid muscles [31–33]. Activities of the suprahyoid muscles using surface electromyography during the tongue press exercise were greater than the activities obtained during the head lift exercise (Shaker Exercise) [32]. Therefore, tongue-strengthening exercise may be useful for training both the tongue and suprahyoid muscles, and it may be simpler and more feasible in a short period of time. However, there has been no report demonstrating that tongue-strengthening exercise is effective for strengthening the suprahyoid muscles.

In a previous study, we investigated the effects of anterior tongue-strengthening exercises on tongue muscle power of the posterior portion in healthy young adults [34]. Maximum tongue pressure (MTP) in both the anterior and posterior portions increased significantly with the anterior tongue-strengthening exercise. Additionally, these training effects were found to continue for more than 3 months after completion of the training. This was the first study to show that the tongue muscle power in the posterior portion increased with anterior tongue-strengthening exercise alone.

The purpose of the present study was to investigate whether tongue-strengthening exercise with a device causes

hypertrophy of the geniohyoid, one of the suprahyoid muscles, in young healthy adults. The area of the geniohyoid muscle was measured using ultrasonic imaging before and after the training to determine the effects of tongue-strengthening exercise on the suprahyoid muscles.

Methods

Subjects

Seven healthy young adults (3 men and 4 women; age range 20–21 years; mean age, 21.0 ± 1.3 years) agreed to participate in this study. The exclusion criteria were as follows: (i) disturbances of mastication and deglutition; (ii) abnormalities in the number or position of teeth except for the third molar; (iii) history of orthodontic treatment or temporomandibular disorders; (iv) abnormalities in oral occlusion; (v) history of major surgery to the head or neck, or oral disease (other than routine tonsillectomy or previous tracheostomy); or (vi) history of neurologic impairment (for example, Parkinson's disease, multiple sclerosis). This study received the approval of the ethics committee of Kawasaki University of Medical Welfare (No. 16-045). Informed consent was obtained from all participants prior to participation in this study.

Method of Training Interventions

All participants performed 8-week tongue muscle training using the JMS Tongue Pressure Measurement Device (TPM-01, JMS Co., Hiroshima, Japan). Figure 1 shows the device, probe, and connecting tube. The balloon type probe was inflated with air at an initial pressure of 19.6 kPa by turning on the switch for pressurization. The diameter of the balloon

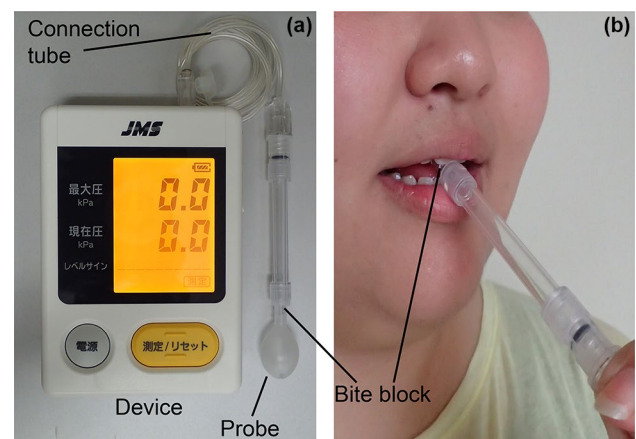
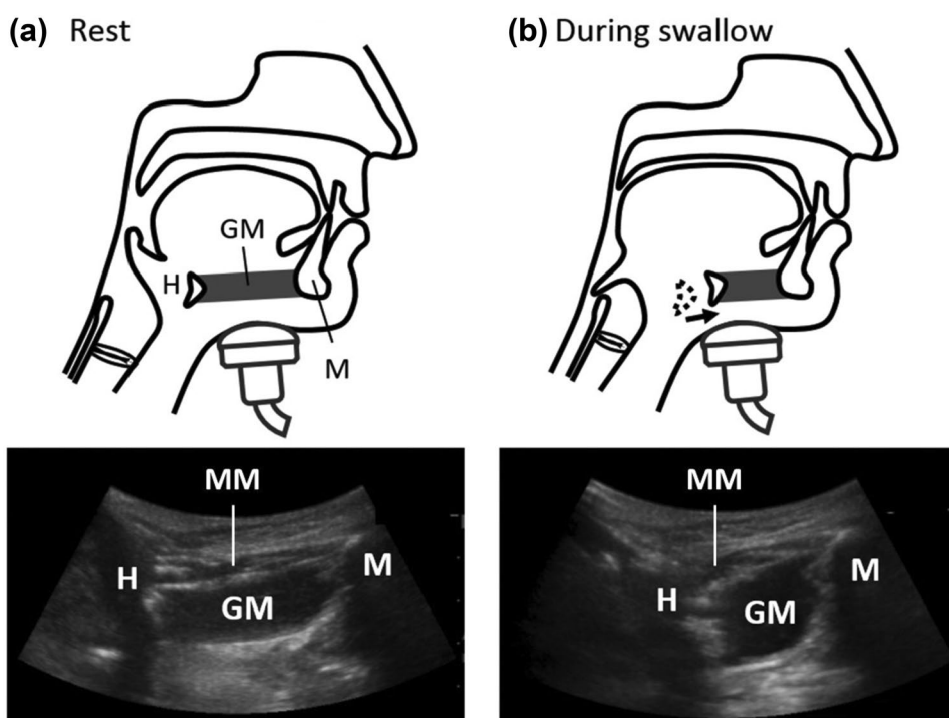


Fig. 1 JMS Tongue Pressure Measurement Device. **a** Measurement device. **b** Measurement setting

Fig. 2 Ultrasonic probe positions (upper frame) and ultrasonic image in the midsagittal plane (lower frame). **a** At rest. **b** Maximum geniohyoid muscle contraction in swallowing. *H* hyoid bone, *M* mandible, *GM* geniohyoid muscle, *MM* mylohyoid muscle



was approximately 18 mm, with a volume of 3.7 ml (Fig. 2a). This pressure was taken as zero calibration. The participant was asked to hold the bite block so that the balloon could be placed between the tongue and the anterior part of the palate. During recordings, both the current and the maximal pressure values were displayed digitally in real time on the screen of the device. The training program involved tongue-strengthening exercise in accordance with the method of Robbins et al. [25]. Participants pressed the anterior tongue against the hard palate 30 times in each session, three sessions a day, 3 days a week. The participants were asked not to take a break for more than three consecutive days. The participants were training under the examiner's supervision during each session.

Prior to starting each session of the training program, the MTP of each participant was measured as the baseline for that day. Each participant was instructed to press the tongue against the hard palate as hard as possible. Measurements were repeated twice in each session. The larger value of these two measurements was regarded as the baseline MTP for each participant.

The exercise intensity was set at 60% of the baseline MTP in each session during the first week of the program, and it was increased to 80% of the baseline MTP in each session during the remaining training program. The device provided visual biofeedback of tongue pressure (kPa) via a numerical display to indicate successful achievement of the target pressure.

Outcome Measures

Maximum Tongue Pressure

MTP was measured by the JMS Tongue Pressure Measurement Device before starting each session of the training program. The measurement method was as described above.

Ultrasonography

Recording Images Ultrasonography was carried out with slight modification based on the method described by Shimizu et al. [35]. Participants were asked to sit upright on a chair. A 2–5-MHz convex probe (SonoSite M turbo, FUJIFILM SonoSite, Tokyo, Japan) was placed on the skin between the mentum and the laryngeal prominence. The direction of the probe was parallel to the sagittal plane (Fig. 2).

The position of the probe was adjusted to visualize the hyoid bone with care so that the surface did not touch the thyroid cartilage. Sufficient ultrasonic gel was applied so that compression of the submental soft tissue could be avoided. The hyoid bone, mandible, and geniohyoid muscle were delineated on a single screen using B-mode (frequency, 3.5 MHz) (Fig. 2a). When the probe was aligned with the midline of the mouth floor and perpendicular to the submental surface, the hyoid bone and mandible were depicted as acoustic shadows. Between the hyoid bone and mandible, the mylohyoid muscle was seen in the surface layer, and the geniohyoid muscle was seen in the deep layer. The ultrasonic

image in the midsagittal plane was recorded three times at rest and saved in the equipment.

While leaving the probe in the submental portion, the participants swallowed saliva or 5 ml of water on command. The pattern of swallowing was of tipper type, in that swallowing was initiated by the tip of the tongue touching the incisors. A subject swallowed saliva and 5 ml of water three times each, for a total of six swallows, according to the examiner's instructions. The order of tasks was randomized for each subject. Contraction of the geniohyoid muscle and movement of the hyoid bone during swallowing were recorded three times (Fig. 2b) and saved as video.

Ultrasonic Evaluation Parameter measurements were performed on a personal computer using the saved ultrasonic images. Image J version 1.43 software (National Institutes of Health, Baltimore, MD, USA) was used for measurements of area and distance, and the video was played and edited at 15 frames/s using Adobe Premiere Elements version 4.0@ software (Adobe Systems Inc., San Jose, CA, USA). The following three parameters were calculated.

- (i) *Area of the geniohyoid muscle at rest* (Fig. 3a): The area of the region surrounding the geniohyoid muscle and its fascia boundary was measured using ultrasonic images at rest.
- (ii) *Shortening of the geniohyoid muscle between resting* (Fig. 3b) *and swallowing* (Fig. 3c): The length of the geniohyoid muscle was measured as the distance between landmarks on the hyoid bone (H) and the mandible (M), which are attached to parts of the muscle. The point of maximal contraction was identified by frame-by-frame reproduction of the video during swallowing. The amount of shortening was calculated by subtracting the distance at the point of maximal contraction (B) from the distance at rest (A).

- (iii) *Contraction ratio of the geniohyoid muscle*: The contraction ratio was calculated by the equation $[(A - B)/A \times 100]$.

Data Analysis

Differences in MTP and the three parameters measured using ultrasonic images between before and after the training program were examined by Wilcoxon's signed-rank test. Statistical analysis was performed using IBM SPSS Statistics Version 23 (IBM Japan, Tokyo, Japan), with significance set at $P < 0.05$.

Results

Maximum Tongue Pressure (MTP)

Mean MTP increased significantly after the 8-week training program (61.6 ± 4.3 kPa) compared to before the program (44.9 ± 5.4 kPa) ($P < 0.05$) (Fig. 4).

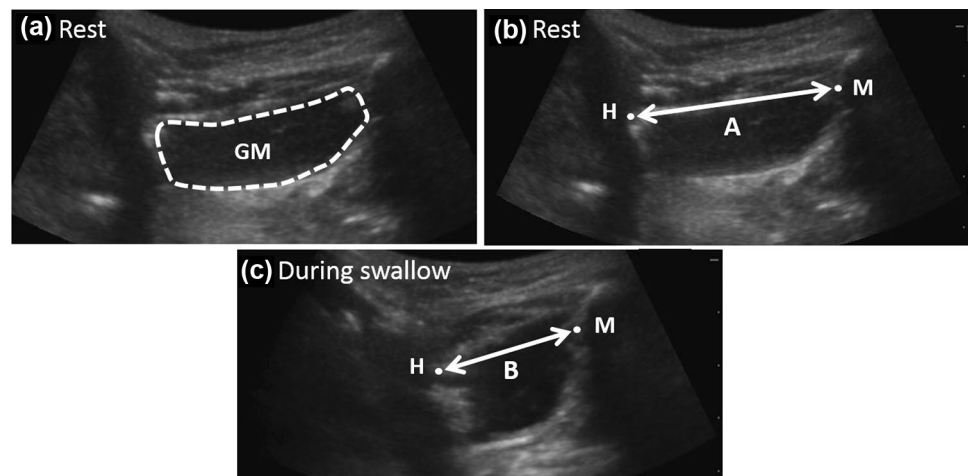
Area of the Geniohyoid Muscle at Rest

The mean area of the geniohyoid muscle was significantly greater after the training program (2.6 ± 0.5 cm²) than before the program (2.3 ± 0.4 cm²) ($P < 0.05$) (Fig. 5).

Shortening Amount and Contraction Ratio of the Geniohyoid Muscle

Table 1 shows the mean length, the amount of shortening, and the contraction ratio of the geniohyoid muscle before and after the 8-week training program. There was no significant difference in the amount of shortening and the contraction ratio of the geniohyoid muscle between before and after the program.

Fig. 3 Evaluation of submental ultrasonic images. **a** Area of the geniohyoid muscle at rest, as the region (dashed line) enclosing the muscle and its fascia boundary. **b** Length of the geniohyoid muscle at rest (A). **c** Shortening amount of the geniohyoid muscle in swallowing (B). *H* hyoid bone, *M* mandible, *GM* geniohyoid muscle



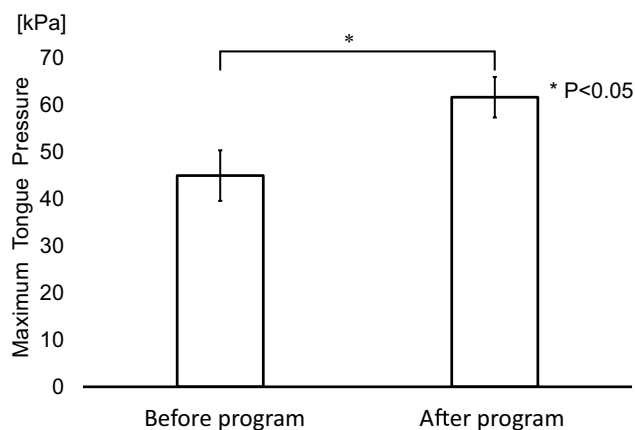


Fig. 4 Comparison of maximum tongue pressures between those before and after the training program

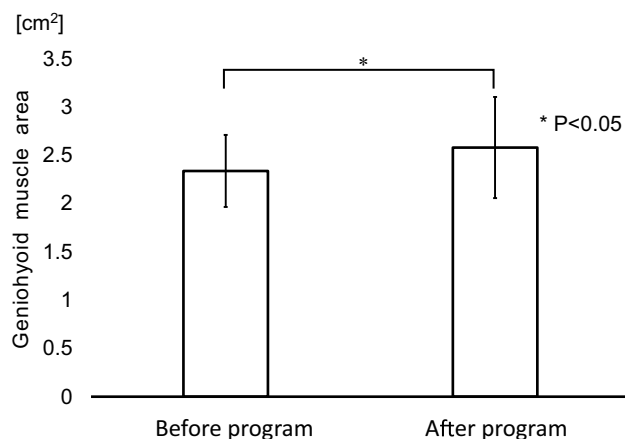


Fig. 5 Comparison of the geniohyoid muscle areas between those before and after the training program

Discussion

Not only the MTP, but also the area of the geniohyoid muscle was shown to increase significantly in healthy young adults after the 8-week tongue muscle training in the present study. In previous studies, methods of

resistance training to the tongue muscles and suprahyoid muscles were reported separately [20, 23–27]. However, no previous report investigated how to strengthen both of them simultaneously. There were several studies of the relationship between tongue muscle contraction and the activities of the suprahyoid muscles [31–33]. Electromyographic activities from submental surface recording were greater during the tongue press exercise than during the head lift exercise [32].

In the present study, the participants continued the tongue muscle training for 8 weeks, which was longer than the 6-week program of the Shaker Exercise reported to increase laryngeal excursion. Given the considerable enlargement of the geniohyoid muscle, the intensity of the suprahyoid muscle contraction induced by the tongue-strengthening exercise in this study may be greater than that induced by the Shaker Exercise. This study was considered valuable as the first report proving that both the tongue and suprahyoid muscles changed with tongue-strengthening exercise alone.

Contractility of the suprahyoid muscles has been generally assessed by measuring vertical and horizontal movements of the hyoid bone using a videofluorographic swallowing study (VFSS) [9, 36, 37]. Although muscle function can be evaluated by measuring bone movement using VFSS, VFSS cannot be used to assess the thickness and cross-sectional area of muscles, as well as other aspects of muscle morphology. Recently, 3-dimensional CT has been reported as a useful tool for evaluating swallowing movements. Although it has excellent temporal and spatial resolution in the analysis of swallowing, there are limitations in available examination facilities and postures of examinees, as well as problems relating to radiation exposure [38]. In contrast, muscles and bones in the submental region can be easily visualized using ultrasonography, so that it is possible to evaluate the movements during swallowing. This instrument is minimally invasive and relatively inexpensive. Since it does not limit the postures of the examinees, it is suitable for bedside use. Since ultrasonic examination has been reported to be reliable and reproducible, it has been established as a method to evaluate movements during swallowing [35, 39, 40]. In the present study, it was confirmed

Table 1 Comparisons of the amounts of shortening and the contraction ratios in the geniohyoid muscle between the values before and after the training program

	Before program (Mean ± SD)	After program (Mean ± SD)	<i>P</i> value
GM length at rest (cm)	3.9 ± 0.2	3.9 ± 0.6	0.866
GM shortening amount during saliva swallow (cm)	2.6 ± 0.4	2.7 ± 0.4	0.499
GM shortening amount during 5 ml liquid swallow (cm)	2.7 ± 0.2	2.7 ± 0.4	1.000
GM contraction ratio during saliva swallow (%)	32.6 ± 10.6	29.8 ± 8.5	0.398
GM contraction ratio during 5 ml liquid swallow (%)	30.8 ± 3.6	30.3 ± 12.5	1.000

GM geniohyoid muscle

that ultrasonography is useful for investigating the effect of tongue muscle training on the geniohyoid muscle.

The increase of geniohyoid muscle area following 8-week tongue muscle training must be the result of muscular hypertrophy. In general, muscular hypertrophy causes an increase in the maximal contraction force [41]. Increased muscle strength of the geniohyoid muscle may affect the extent of hyoid bone movement, opening of the upper esophageal sphincter (UES), and a decrease in the UES pressure during swallowing [15]. However, the shortening amount and contraction ratio of the geniohyoid muscle were not changed in the present study after the 8-week tongue muscle training. The reason for this is considered to be that the participants were healthy young adults with sufficiently strong swallowing-related muscles. That is, the amount of shortening reached the maximum for the young participants. In other words, the distance between the landmarks on the hyoid bone (H) and mandible (M) could not be narrowed any further.

Although it was a natural result that the strength of the tongue muscle increased with the tongue strength training, why did the strength of the suprahyoid muscles increase after the tongue strength training in this study? Palmer et al. explained that pressing the tongue against the palate is achieved not only by activation of the tongue muscles, but also by the cooperative action of the floor-of-mouth muscles and the jaw-closing muscles [33]. If the tongue press exercise was done without causing contraction of the suprahyoid muscles, tongue pressure would not have been maximized in this study. There is no doubt that co-contraction of the floor-of-mouth muscles including the geniohyoid muscle is necessary during tongue press exercise.

Since strength of both the tongue and suprahyoid muscles increased with tongue-strengthening exercise alone, this training has the possibility to improve swallowing function in both the oral and pharyngeal stages for patients with dysphagia. In cases with both reduced laryngeal elevation and weakness in tongue muscle strength, the tongue-strengthening exercise might be useful for improvement of their swallowing dysfunction. Additionally, this exercise may be useful for self-training at home to prevent aspiration pneumonia and malnutrition in elderly people, because it might be simple, effective, and feasible in a short period of time. The limitations of the present study include that the functional effects of the increase in suprahyoid muscles was not clear. Further studies are needed to clarify the effectiveness of tongue muscle-strengthening exercises for elderly people and patients with dysphagia in the future. Furthermore, more data on comparisons between the Shaker Exercise and this exercise and differences based on length of training need to be collected in order to understand the ability of healthy elderly and elderly persons with dysphagia to follow through with this at home.

Conclusions

Both the MTP and the area of the geniohyoid muscle increased significantly in healthy young adults after the 8-week tongue muscle training. It appears that both the tongue and suprahyoid muscles could be increased by the tongue-strengthening exercise alone.

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Author contributions JY contributed in conceiving study concept, analyzing data, and drafting manuscript. SYS and TY helped in conceiving the study concept, data collection, and interpretation. IK, KH, and AT conceived the study and supervised the whole project. All authors read and approved the final manuscript.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics Approval and Consent to Participate The protocol was approved by the ethics committee of Kawasaki University of Medical Welfare (No. 16-045), and all participants provided written, informed consent.

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