Archives of Oral Biology 98 (2019) 238–242

Contents lists available at ScienceDirect

Archives of Oral Biology

journal homepage: www.elsevier.com/locate/archoralbio

# Effects of anterior tongue strengthening exercises on posterior tongue strength in healthy young adults

Jitsuro Yano[a,*], Sayako Yamamoto-Shimizu[b], Tomonori Yokoyama[c,d], Isami Kumakura[e], Kozo Hanayama[b], Akio Tsubahara[f]

[a] *Department of Sensory Science, Faculty of Healthy Science and Technology, Kawasaki University of Medical Welfare, 288 Matsushima, Kurashiki, Okayama 701-0193, Japan*

[b] *Department of Rehabilitation Medicine, Kawasaki Medical School, 577 Matsushima, Kurashiki, Okayama 701-0192, Japan*

[c] *Department of Speech-Language-Hearing Therapy, Rehabilitation Center, Kawasaki Medical School Hospital, 577 Matsushima, Kurashiki, Okayama 701-0192, Japan*

[d] *Department of Occlusal and Oral Functional Rehabilitation, Graduate School of Medicine, Dentistry and Pharmaceutical Sciences, Okayama University, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8525, Japan*

[e] *Senri Rehabilitation Hospital, 4-6-1 Onoharanishi, Minoh, Osaka 562-0032, Japan*

[f] *Kawasaki University of Medical Welfare, 288 Matsushima, Kurashiki, Okayama 701-0193, Japan*

A R T I C L E I N F O

*Keywords:*
Tongue strength
Tongue pressure
Exercise
Swallowing
Dysphagia

A B S T R A C T

*Objective:* The aim of the present study was to investigate whether anterior tongue muscle strengthening exercises can affect the strength of posterior tongue muscles.

*Design:* Eleven healthy subjects (20.6 ± 1.2 years) were included. The subjects exercised by pushing the anterior tongue to the palate 30 times, three times a day, 3 days a week for 8 weeks. The exercise intensity was set at 60% of maximum tongue pressure (MTP) in the first week and 80% of MTP for the remainder of training. After the completion of training, MTP measurements were continued every month for another 3 months to evaluate whether training effects were sustained.

*Results:* MTP was significantly increased after 8 weeks of training compared with before training. No significant differences were seen between MTP immediately after completion of training and MTP 1–3 months after completion of training. However, MTP was significantly higher 1–3 months after completion of training than before training.

*Conclusions:* The present study showed significant increases in both anterior and posterior MTPs by anterior tongue muscle strengthening exercises. In the future, a database on tongue muscle strengthening exercises in elderly persons, patients with dysphagia, etc. will need to be generated, with the aim of preventing frailty.

## 1. Introduction

The tongue plays a role in bolus holding within the oral cavity and bolus transport from the oral cavity to the pharynx (Dodds, 1989; Hiiemae, Hayenga, & Reese, 1995; Palmer, Hiiemae, & Liu, 1997; Palmer, 1998), and the base of the tongue generates swallowing pressure within the pharynx (Cerenko, McConnel, & Jackson, 1989; McConnel, 1988).

One indicator used to evaluate motor function of the tongue is the force of the tongue pressing against the palate (tongue pressure). High tongue pressure is important in bolus transport (Kahrilas, Lin, Logemann, Ergun, & Facchini, 1993) and also has an effect on internal pharyngeal pressure (Juan et al., 2013; Ohno, Ohno, & Fujishima, 2017). Muscle weakness of the tongue is seen in many patients with dysphagia caused by cerebrovascular diseases (Hirota et al., 2010; Hori, Ono, Iwata, Nokubi, & Kumakura, 2005; Konaka et al., 2010), neuromuscular diseases (Hamanaka-Kondoh et al., 2014; Hiraoka et al., 2017), and head and neck cancers (Hamahata et al., 2014; Hasegawa et al., 2017; White, Cotton, Hind, Robbins, & Perry, 2009). When tongue-pressure generation is impaired, liquids may spill into the pharynx before the airway is protected, or bolus clearance may be impaired, leaving residue in the pharynx (Steele et al., 2013, 2016).

*Abbreviations:* MTP, maximum tongue pressure; IOPI, Iowa oral performance instrument; IQR, interquartile range

* Corresponding author.

*E-mail addresses:* yano@mw.kawasaki-m.ac.jp (J. Yano), s-shimizu@med.kawasaki-m.ac.jp (S. Yamamoto-Shimizu), t_yokoyama1127@yahoo.co.jp (T. Yokoyama), kumakurakobe@gmail.com (I. Kumakura), hanayama@med.kawasaki-m.ac.jp (K. Hanayama), tsuba@med.kawasaki-m.ac.jp (A. Tsubahara).

https://doi.org/10.1016/j.archoralbio.2018.11.028
Received 23 August 2018; Received in revised form 21 November 2018; Accepted 27 November 2018
0003-9969/ 

Traditional oral motor exercises include tongue range of motion, tongue resistance, and bolus control activities (Groher & Crary, 2016; Logemann, 1999). In addition, several reports have noted that increased tongue pressure improved swallowing function (Juan et al., 2013; Ohno et al., 2017; Park, Kim, & Oh, 2015; Robbins et al., 2007; Steele et al., 2013, 2016). Tongue pressure generation is related to functional aspects of swallowing physiology, such as bolus propulsion from the oral cavity to the pharynx and from there to the esophagus (Huckabee & Steele, 2006; Steele & Huckabee, 2007; Yano et al., 2014, 2018). The ability to generate higher tongue pressure as a result of tongue strengthening exercises might improve oral and pharyngeal bolus clearance (Robbins et al., 2007; Steele et al., 2013, 2016). Therefore, tongue muscle strengthening exercises to increase tongue pressure are also considered important in the prevention of sarcopenia in elderly persons, as well as in swallowing rehabilitation (Maeda & Akagi, 2015; Sakai et al., 2017; Tamura, Kikutani, Tohara, Yoshida, & Yaegaki, 2012).

During swallowing, the tongue plays a role in the pharyngeal phase, as well as in the oral phase. Recent studies reported that tongue muscle strengthening exercises involved the training of both the anterior and posterior parts of the tongue (Oh, 2015; Park et al., 2015; Robbins et al., 2007; Steele et al., 2013, 2016). These studies reported improved tongue strength in both the anterior and posterior parts of the tongue.

The JMS Tongue Pressure Measurement Device (JMS device) is widely used in Japan (Hasegawa et al., 2017; Hiraoka et al., 2017; Mihara et al., 2018; Morisaki, Miura, & Hara, 2015; Shimizu et al., 2018; Takahashi, Koide, Arakawa, & Mizuhashi, 2013). The device probe includes a bite block. This device can measure the tongue strength of the anterior part, but it cannot measure the tongue strength of the posterior part. Therefore, there are currently no reports of the effects of anterior tongue strengthening exercises on posterior tongue strength without involving direct exercise of this region.

In the present study, tongue muscle training was performed for 8 weeks using the JMS device, and tongue pressure was measured before and after the training using the Iowa Oral Performance Instrument (IOPI) (Oh, 2015; Park et al., 2015; Robbins et al., 2007; Steele et al., 2013). The changes in tongue pressure were monitored for 3 months after the completion of training. The effects of tongue strengthening exercise were compared between the anterior and posterior parts of the tongue in healthy young adults. The purpose of this research was to investigate whether anterior tongue muscle strengthening exercises affect posterior tongue muscle strength.

## 2. Materials and methods

### 2.1. Subjects

The subjects were 11 healthy young adults without swallowing or articulation disorders (3 men and 8 women; age range, 20–21 years; mean age, 20.6 ± 1.2 years) who had given their written, informed consent prior to the study. This study received approval from the ethics committee of Kawasaki University of Medical Welfare (No. 16-045).

### 2.2. Equipment for training and pressure measurement

#### 2.2.1. JMS tongue pressure measurement device

The JMS Tongue Pressure Measurement Device (TPM-01, JMS Co., Hiroshima, Japan) was used for the 8-week training program. Fig. 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 was approximately 18 mm, with a volume of 3.7 ml (Fig. 2a). This pressure was taken as zero calibration. The subject 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, current and maximal pressure values were displayed digitally on the screen of the device in real time.

#### 2.2.2. Iowa oral performance instrument (IOPI)

The IOPI (IOPI MEDICAL LLC, Woodinville, WA, USA) was used to measure anterior and posterior maximum tongue pressures (MTPs). The IOPI records the tongue pressure using an air-filled plastic probe through the connecting tube to the device. The probe is approximately 12 mm in diameter, with a volume of 2.8 ml (Fig. 2b).

### 2.3. Method of training interventions

All subjects performed 8-week tongue muscle strengthening training using the JMS device. The training program involved tongue muscle strengthening exercises in accordance with the method of Robbins et al. (2005), which involved subjects performing an 8-week lingual exercise program consisting of compressing an air-filled bulb between the tongue and hard palate using the IOPI. The subjects exercised the tongue blade 30 times, three times a day, 3 days a week. The subjects exercised with a goal of 60% of the baseline MTP for the first week of the program and 80% of the MTP for the remaining 7 weeks. Baseline measurements were performed at the ends of weeks 2, 4, and 6, and the 80% target was recalculated.

In this study, subjects pushed the anterior tongue to the hard palate 30 times, three times a day, 3 days a week, and the subjects were asked not to take a rest for more than three days consecutively. Before starting the training program, the baseline MTP of each subject was measured. After the subjects exercised with a goal of 60% of baseline MTP during the first week of the program, exercise intensity was raised to 80% of MTP for the remainder of the study. The JMS device was used to determine the exercise intensity in the training. The device provided visual biofeedback of pressure generation (kPa) via a numerical display to indicate successful achievement of the target pressure. The achievement of exercise was confirmed by the display of the JMS device.

Even after completing the training program, MTP measurements were continued every month for another 3 months to evaluate whether the training effects were sustained. All subjects were instructed to carry on their normal lifestyles and avoid special strengthening exercises of the tongue for the next 3 months. It was confirmed that subjects were avoiding exercises of the tongue when they were evaluated after completing the program. Furthermore, the JMS device was kept in the laboratory so that the subjects did not use it.

### 2.4. Method of measuring maximum tongue pressure

MTP was measured using the IOPI. Each subject was instructed to press the tongue against the probe of the IOPI as hard as possible.

The anterior MTP was measured with the flat front end of the probe positioned just behind the teeth. The posterior MTP was measured with the probe positioned at the posterior edge of the first molar tooth. Each measurement was repeated twice. The MTP was selected as the maximum value of two trials for each subject.

MTPs were taken at baseline, at the end of each week of the training program, and each month after completing the program by the IOPI in the laboratory.

### 2.5. Statistical analysis

MTPs were statistically compared during the training and at completion of training using Friedman's test with the post hoc Wilcoxon signed-rank test and Bonferroni correction. The relationship between changes in anterior and posterior MTPs was analyzed using Spearman's rank correlation coefficient. Statistical analysis was performed using IBM SPSS Statistics version 24 (IBM Japan, Tokyo, Japan), with significance set at $P < 0.05$.

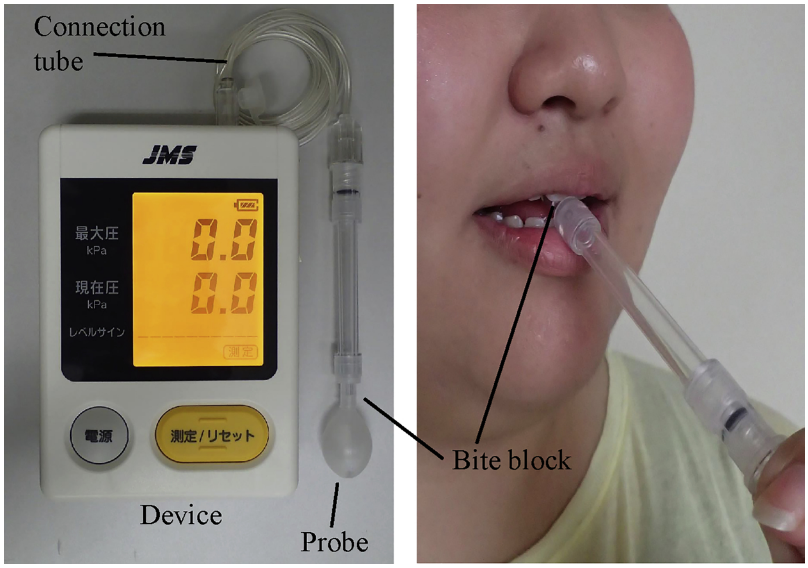


**Fig. 1.** JMS Tongue Pressure Measurement Device.

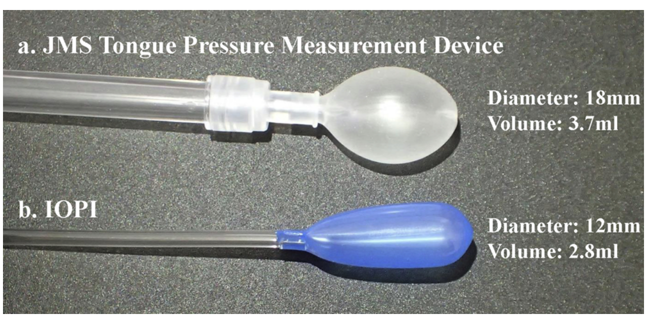


**Fig. 2.** Probes for tongue pressure measurement.
a. JMS Tongue Pressure Measurement Device.
b. Iowa Oral Performance Instrument.

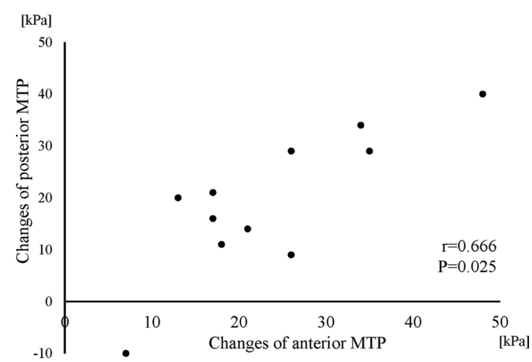


**Fig. 3.** Relationship between changes in anterior and posterior maximum tongue pressures.

## 3. Results

### 3.1. Effects of the training program on MTP

The anterior and posterior MTPs after the 8-week training program are shown in Table 1. MPTs were compared to baseline. The anterior and posterior MTPs increased significantly from the third week to the eighth week after starting the training program compared with the baseline ($P < 0.05$).

The median change in the anterior MTP before and after the 8-week training program was 21 kPa (interquartile range [IQR] 17-30 kPa, 41.2% increase), and that in the posterior MTP was 20 kPa (IQR 12.5-29 kPa, 43.2% increase). The relationship between changes in anterior and posterior MTPs is shown in Fig. 3. Changes in the anterior MTP correlated significantly with those in the posterior MTP ($r = 0.666$, $P = 0.025$).

**Table 1**
Effects of training on maximum tongue pressure.

| | Maximum Tongue Pressure (kPa) | | | | | |
|---|---|---|---|---|---|---|
| | Anterior | | | Posterior | | |
| | Median (IQR) | | P value | Median (IQR) | | P value |
| Baseline | 53 | (51–62) | | 38 | (35–51) | |
| 1 week | 54 | (49–71) | 1.000 | 47 | (34–61) | 0.234 |
| 2 week | 61 | (56–75) | 0.209 | 49 | (43–62) | 0.115 |
| 3 week | 67 | (62–74) | 0.036* | 55 | (50–66) | 0.027* |
| 4 week | 70 | (67–78) | 0.027* | 58 | (50–67) | 0.027* |
| 5 week | 70 | (65–73) | 0.027* | 58 | (52–68) | 0.027* |
| 6 week | 70 | (67–81) | 0.027* | 58 | (50–65) | 0.04* |
| 7 week | 72 | (70–83) | 0.027* | 59 | (52–70) | 0.027* |
| 8 week | 77 | (72–84) | 0.027* | 57 | (55–67) | 0.047* |

Significant difference versus baseline * $P < 0.05$.

### 3.2. MTP after completion of the training program

None of the subjects performed the special strengthening exercises of the tongue after completing the training program. MTPs for 3 months after completing the 8-week training program are shown in Table 2. There were no significant differences between MTPs at the end of the training program and those 1–3 months after completion of training. Needless to say, MTPs were significantly higher 1–3 months after completion of training than before the training program ($P < 0.05$ each). MTPs were maintained without further exercise in the 3-month detraining period.

## 4. Discussion

In the present study, the effects of anterior tongue muscle strengthening exercises on tongue muscle force of the posterior part were investigated in healthy young adults. Both anterior and posterior maximum tongue pressures increased significantly with the anterior tongue muscle strengthening exercise. Additionally, these training effects were found to last for more than several months after completing

**Table 2**
Maximum tongue pressure after completion of training.

| | Maximum Tongue Pressure (kPa) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Anterior | | | | Posterior | | | |
| | | | P value | | | | P value | |
| | Median (IQR) | | vs Baseline | vs COT | Median (IQR) | | vs Baseline | vs COT |
| Baseline | 53 | (51–62) | | | 38 | (35–51) | | |
| COT | 77 | (72–84) | 0.023* | | 57 | (55–67) | 0.041* | |
| 1 month after COT | 75 | (73–88) | 0.023* | 1.000 | 67 | (62–76) | 0.023* | 0.367 |
| 2 month after COT | 76 | (72–88) | 0.023* | 1.000 | 69 | (63–71) | 0.023* | 0.912 |
| 3 month after COT | 75 | (74–86) | 0.023* | 1.000 | 63 | (57–72) | 0.023* | 1.000 |

COT completion of training.
Significant difference versus baseline * $P < 0.05$.

the training. Many previous studies have provided tongue muscle training (Oh, 2015; Park et al., 2015; Robbins et al., 2005, 2007; Steele et al., 2013, 2016). From the present study, it became clear for the first time that the tongue strength of the posterior part increased with increases in anterior tongue muscle strength due to anterior tongue muscle strengthening exercise alone. The reason for the effect in the present study seems to be the special structure of the tongue muscle. The tongue is composed of extrinsic (genioglossus, hyoglossus, styloglossus, palatoglossus) and intrinsic tongue muscles (transverse, vertical, superior longitudinal, inferior longitudinal muscles). These tongue muscles form complex networks (Felton, Gaige, Reese, Wedeen, & Gilbert, 2007; Gilbert, Napadow, Gaige, & Wedeen, 2007; Takemoto, 2008). The anterior and posterior parts of the tongue muscles cannot contract independently. They are interlinked for contraction in a complicated manner. The tongue is a muscular hydrostat, an organ without skeletal support (Sanders & Mu, 2013). The volume of a hydrostat remains constant during muscle contractions. The tongue muscle is organized into both intrinsic and extrinsic muscle fibers that function synergistically. These combined contractions change the tongue position and shape, thus maintaining the hydrostatic condition (Felton et al., 2007; Gilbert et al., 2007). Therefore, the posterior part of the tongue muscles must contract when the anterior part of the tongue muscles moves.

Among the previous studies with repeated tongue muscle strengthening exercises, the present training program involved tongue muscle strengthening exercises in accordance with the method of Robbins et al. (2005). This is recommended for strength training by the American College of Sports Medicine (American College of Sports Medicine position stand, 1990). The present study in terms of subjects and training was most similar to the research by Oh (Oh, 2015). As a result of training of both anterior and posterior parts of the tongue muscles for 30 min using the IOPI, anterior maximum tongue pressure (from 64.5 kPa before training to 80.5 kPa after training; 25% increase) and posterior maximum tongue pressure (from 60.8 kPa before training to 76.4 kPa after training; 26% increase) increased significantly in their study. The present study using the JMS device confirmed that the training was more effective and obtained larger increases in both anterior (46.1% increase) and posterior (53.6% increase) maximum tongue pressures than their method. However, different subjects, protocols, and devices used for tongue muscle strengthening exercises make direct comparisons between the study by Oh and the present study impossible.

The reason for the effect in the present study is considered to be the difference in probe shape between the IOPI and the JMS device (Fig. 2). The probe of the IOPI has a balloon in the point of a thin tube, with no bite block. The force used in training using the IOPI is supplied by the tongue lifting force and the jaw closing force. On the other hand, the probe of the JMS device includes a bite block. The jaw position remains the same due to the bite block during training using the JMS device. The force used in the training using the JMS device is supplied only by the tongue lifting force. Therefore, the training using the JMS device may involve more intensive tongue muscle strengthening exercise than that using the IOPI. A previous study reported that the maximum tongue strength measured by the IOPI (there was interincisor separation, but the space between the incisors with the IOPI was narrower than with the JMS device) was slightly higher than that measured by the JMS device (Yoshikawa, Yoshida, Tsuga, Akagawa, & Groher, 2010). Furthermore, the diameter and volume of the probe are greater with the JMS device than with the IOPI. These differences in diameters and volumes of the probes between the JMS device and the IOPI may also have affected the results.

The period of the tongue muscle strengthening exercise in previous research varied: 4 weeks (Lazarus, Logemann, Huang, & Rademaker, 2003), 6 weeks (Park et al., 2015), 8 weeks (Oh, 2015; Robbins et al., 2005, 2007), and 8–12 weeks (Steele et al., 2013, 2016). The period of the present study was 8 weeks. As a result, the maximum tongue pressure for 1–3 months after completion of training was significantly higher than that before the training program. Factors related to muscle hypertrophy were said to increase from about 6–10 weeks after the start of exercise in skeletal muscles (Kraemer, Fleck, & Evans, 1996). The maintenance of training effects for 3 months after training in the present study might have been caused by hypertrophy of the tongue muscles. The maintenance of the training effect might depend on not only the high number of repetitions and the number of days of exercise, but also the training period.

The limitations of the present study include the differences in bulb size between the JMS device and IOPI, the limited sample size of only 11 healthy young adults, and the subjects' limited age range. Differences in subjects, protocols, and devices used for tongue muscle strengthening exercises between this and other studies also make direct comparisons of outcomes difficult. Further development of the tongue muscle strengthening exercises using the JMS device is needed. The primary outcome in the present study was the efficacy of the exercises. However, the contribution of the JMS device is not clear. To clarify its contribution, a comparison of the results of training using the IOPI with the same protocol as this study and the results of the present study will be necessary. More data on tongue muscle strengthening exercises under various conditions (in healthy elderly individuals, etc.) need to be collected and analyzed in the future to prevent frailty in elderly individuals and to apply this training to patients with dysphagia.

## 5. Conclusion

The usefulness of an 8-week anterior tongue muscle strengthening exercise program in healthy young adults using the JMS device was confirmed in the present study.

The results showed significant increases in both anterior and posterior maximum tongue pressures. The training effects were proven to last for more than several months after completion of the training program.

In the future, a database on tongue muscle strengthening exercises in healthy elderly persons, patients with dysphagia, etc. will need to be generated, with the aim of preventing frailty.

## Author's contributions

All authors materially participated in the research or article preparation. Below all authors will be listed and the contribution of each of them in the study will be specified.

**Jitsuro Yano** participated in the conception of the idea, study design drafting of the article, acquisition of data, analysis and interpretation of data, and final approval of the article.

**Sayako Yamamoto-Shimizu** participated in critical review of the article, data acquisition and final approval of the article.

**Tomonori Yokoyama** participated in the design of the study, critical review of the article and final approval of the article.

**Isami Kumakura** participated in the design of the study, critical review of the article and final approval of the article.

**Kozo Hanayama** participated in critical review of the article, data acquisition and final approval of the article.

**Akio Tsubahara** participated in the conception of the idea, study design drafting of the article, analysis and interpretation of data, critical review of the article and final approval of the article.

## Funding

This study was supported by the Kawasaki Foundation for Medical Science & Medical Welfare (Japan, No grant ID), Kawasaki University of Medical Welfare Scientific Research Fund (Japan, No grant ID).

## Conflict of interest

None of the authors have any commercial or financial involvement in connection with this study that represent or appear to represent any conflicts of interest.

## References

American College of Sports Medicine position stand (1990). The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness in healthy adults. *Medicine and Science in Sports and Exercise, 22*, 265–274.

Cerenko, D., McConnel, F. M., & Jackson, R. T. (1989). Quantitative assessment of pharyngeal bolus driving forces. *Otolaryngology–Head and Neck Surgery : Official Journal of American Academy of Otolaryngology-Head and Neck Surgery, 100*, 57–63.

Dodds, W. J. (1989). Physiology of swallowing. *Dysphagia, 3*, 171–178.

Felton, S. M., Gaige, T. A., Reese, T. G., Wedeen, V. J., & Gilbert, R. J. (2007). Mechanical basis for lingual deformation during the propulsive phase of swallowing as determined by phase-contrast magnetic resonance imaging. *Journal of Applied Physiology, 103*, 255–265.

Gilbert, R. J., Napadow, V. J., Gaige, T. A., & Wedeen, V. J. (2007). Anatomical basis of lingual hydrostatic deformation. *The Journal of Experimental Biology, 210*, 4069–4082.

Groher, M. E., & Crary, M. A. (2016). *Dysphagia : Clinical management in adults and children.* Missouri: Elsevier.

Hamahata, A., Beppu, T., Shirakura, S., Hatanaka, A., Yamaki, T., Saitou, T., ... Sakurai, H. (2014). Tongue pressure in patients with tongue cancer resection and reconstruction. *Auris, Nasus, Larynx, 41*, 563–567.

Hamanaka-Kondoh, S., Kondoh, J., Tamine, K., Hori, K., Fujiwara, S., Maeda, Y., ... Ono, T. (2014). Tongue pressure during swallowing is decreased in patients with Duchenne muscular dystrophy. *Neuromuscular Disorders : NMD, 24*, 474–481.

Hasegawa, Y., Sugahara, K., Fukuoka, T., Saito, S., Sakuramoto, A., Horii, N., ... Kishimoto, H. (2017). Change in tongue pressure in patients with head and neck cancer after surgical resection. *Odontology, 105*(4), 494–503.

Hiiemae, K. M., Hayenga, S. M., & Reese, A. (1995). Patterns of tongue and jaw movement in a cinefluorographic study of feeding in the macaque. *Archives of Oral Biology, 40*(3), 229–246.

Hiraoka, A., Yoshikawa, M., Nakamori, M., Hosomi, N., Nagasaki, T., Mori, T., ... Tsuga, K. (2017). Maximum tongue pressure is associated with swallowing dysfunction in ALS patients. *Dysphagia, 32*, 542–547.

Hirota, N., Konaka, K., Ono, T., Tamine, K., Kondo, J., Hori, K., ... Naritomi, H. (2010). Reduced tongue pressure against the hard palate on the paralyzed side during swallowing predicts dysphagia in patients with acute stroke. *Stroke, 41*, 2982–2984.

Hori, K., Ono, T., Iwata, H., Nokubi, T., & Kumakura, I. (2005). Tongue pressure against hard palate during swallowing in post-stroke patients. *Gerodontology, 22*, 227–233.

Huckabee, M. L., & Steele, C. M. (2006). An analysis of lingual contribution to submental surface electromyographic measures and pharyngeal pressure during effortful swallow. *Archives of Physical Medicine and Rehabilitation, 87*, 1067–1072.

Juan, J., Hind, J., Jones, C., McCulloch, T., Gangnon, R., & Robbins, J. (2013). Case study: Application of isometric progressive resistance oropharyngeal therapy using the madison oral strengthening therapeutic device. *Topics in Stroke Rehabilitation, 20*, 450–470.

Kahrilas, P. J., Lin, S., Logemann, J. A., Ergun, G. A., & Facchini, F. (1993). Deglutitive tongue action: Volume accommodation and bolus propulsion. *Gastroenterology, 104*, 152–162.

Konaka, K., Kondo, J., Hirota, N., Tamine, K., Hori, K., Ono, T., ... Naritomi, H. (2010). Relationship between tongue pressure and dysphagia in stroke patients. *European Neurology, 64*, 101–107.

Kraemer, W. J., Fleck, S. J., & Evans, W. J. (1996). Strength and power training: Physiological mechanisms of adaptation. *Exercise and Sport Sciences Reviews, 24*, 363–397.

Lazarus, C., Logemann, J. A., Huang, C. F., & Rademaker, A. W. (2003). Effects of two types of tongue strengthening exercises in young normals. *Folia Phoniatrica et Logopaedica : Official Organ of the International Association of Logopedics and Phoniatrics (IALP), 55*, 199–205.

Logemann, J. A. (1999). *Evaluation and treatment of swallowing disorders* (2nd edition). Texas: PRO-ED, Inc.

Maeda, K., & Akagi, J. (2015). Decreased tongue pressure is associated with sarcopenia and sarcopenic dysphagia in the elderly. *Dysphagia, 30*, 80–87.

McConnel, F. M. (1988). Analysis of pressure generation and bolus transit during pharyngeal swallowing. *Laryngoscope, 98*, 71–78.

Mihara, Y., Matsuda, K. I., Ikebe, K., Hatta, K., Fukutake, M., Enoki, K., ... Maeda, Y. (2018). Association of handgrip strength with various oral functions in 82- to 84-year-old community-dwelling Japanese. *Gerodontology*. https://doi.org/10.1111/ger.12341.

Morisaki, N., Miura, H., & Hara, S. (2015). Relationship between the nutritional status and the oral function among community-dwelling dependent elderly persons. *Nihon Ronen Igakkai Zasshi Japanese Journal of Geriatrics, 52*, 233–242.

Oh, J. C. (2015). Effects of tongue strength training and detraining on tongue pressures in healthy adults. *Dysphagia, 30*, 315–320.

Ohno, T., Ohno, R., & Fujishima, I. (2017). ). Effect of palatal augmentation prosthesis on pharyngeal manometric pressure in a patient with functional dysphagia: A case report. *Journal of Prosthodontic Research, 61*(4), 460–463.

Palmer, J. B. (1998). Bolus aggregation in the oropharynx does not depend on gravity. *Archives of Physical Medicine and Rehabilitation, 79*, 691–696.

Palmer, J. B., Hiiemae, K. M., & Liu, J. (1997). Tongue-jaw linkages in human feeding: a preliminary videofluorographic study. *Archives of Oral Biology, 42*(6), 429–441.

Park, J. S., Kim, H. J., & Oh, D. H. (2015). Effect of tongue strength training using the Iowa oral performance instrument in stroke patients with dysphagia. *Journal of Physical Therapy Science, 27*, 3631–3634.

Robbins, J., Gangnon, R. E., Theis, S. M., Kays, S. A., Hewitt, A. L., & Hind, J. A. (2005). The effects of lingual exercise on swallowing in older adults. *Journal of the American Geriatrics Society, 53*, 1483–1489.

Robbins, J., Kays, S. A., Gangnon, R. E., Hind, J. A., Hewitt, A. L., Gentry, L. R., ... Taylor, A. J. (2007). The effects of lingual exercise in stroke patients with dysphagia. *Archives of Physical Medicine and Rehabilitation, 88*, 150–158.

Sakai, K., Nakayama, E., Tohara, H., Maeda, T., Sugimoto, M., Takehisa, T., ... Ueda, K. (2017). Tongue strength is associated with grip strength and nutritional status in older adult inpatients of a rehabilitation hospital. *Dysphagia, 32*, 241–249.

Sanders, I., & Mu, L. (2013). A three-dimensional atlas of human tongue muscles. *The Anatomical Record, 296*, 1102–1114.

Shimizu, Y., Sato, S., Noguchi, Y., Koyamatsu, J., Yamanashi, H., Higashi, M., ... Maeda, T. (2018). Association between tongue pressure and subclinical carotid atherosclerosis in relation to platelet levels in hypertensive elderly men: A cross-sectional study. *Environmental Health and Preventive Medicine, 18*(1), 31. https://doi.org/10.1186/s12199-018-0720-5 23.

Steele, C. M., Bailey, G. L., Polacco, R. E., Hori, S. F., Molfenter, S. M., Oshalla, M., ... Yeates, E. M. (2013). Outcomes of tongue-pressure strength and accuracy training for dysphagia following acquired brain injury. *International Journal of Speech-language Pathology, 15*, 492–502.

Steele, C. M., Bayley, M. T., Peladeau-Pigeon, M., Nagy, A., Namasivayam, A. M., Stokely, S. L., ... Wolkin, T. (2016). A randomized trial comparing two tongue-pressure resistance training protocols for post-stroke dysphagia. *Dysphagia, 31*, 452–461.

Steele, C. M., & Huckabee, M. L. (2007). The influence of orolingual pressure on the timing of pharyngeal pressure events. *Dysphagia, 22*, 30–36.

Takahashi, M., Koide, K., Arakawa, I., & Mizuhashi, F. (2013). Association between perioral muscle pressure and masticatory performance. *Journal of Oral Rehabilitation, 40*, 909–915.

Takemoto, H. (2008). Morphological analyses and 3D modeling of the tongue musculature of the chimpanzee (Pan troglodytes). *American Journal of Primatology, 70*(10), 966–975.

Tamura, F., Kikutani, T., Tohara, T., Yoshida, M., & Yaegaki, K. (2012). Tongue thickness relates to nutritional status in the elderly. *Dysphagia, 27*, 556–561.

White, R., Cotton, S. M., Hind, J., Robbins, J., & Perry, A. (2009). A comparison of the reliability and stability of oro-lingual swallowing pressures in patients with head and neck cancer and healthy adults. *Dysphagia, 24*, 137–144.

Yano, J., Aoyagi, Y., Ono, T., Hori, K., Yamaguchi, W., Fujiwara, S., ... Kumakura, I. (2018). Effect of bolus volume and flow time on temporospatial coordination in oropharyngeal pressure production in healthy subjects. *Physiology & Behavior, 15*, 92–98.

Yano, J., Aoyagi, Y., Ono, T., Hori, K., Yamaguchi, W., Fujiwara, S., ... Tsubahara, A. (2014). Sequential coordination between lingual and pharyngeal pressures produced during dry swallowing. *BioMed Research International*. https://doi.org/10.1155/2014/691352.

Yoshikawa, M., Yoshida, M., Tsuga, K., Akagawa, Y., & Groher, M. E. (2010). Comparison of three types of tongue pressure measurement devices. *Dysphagia, 26*, 232–237.