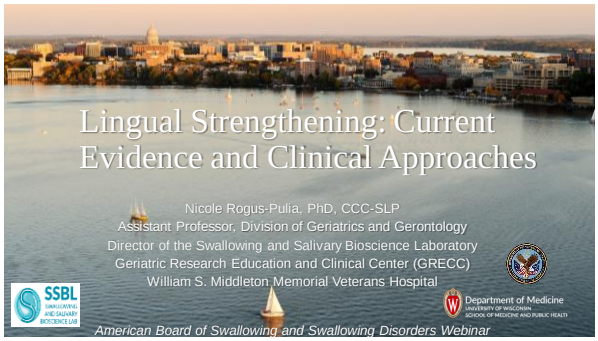

1

Learning Objectives

1. Discuss importance of adequate lingual function for safe and efficient swallowing.
2. Describe the various approaches to lingual strengthening and devices used to facilitate this intervention approach.
3. Review the current evidence for lingual strengthening as well as limitations to prior studies.
4. Discuss the role of patient adherence and dose delivered in observed outcomes of lingual strengthening.

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Lingual Function and Its Role in Swallowing

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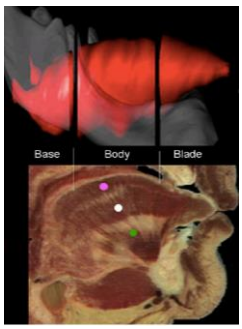
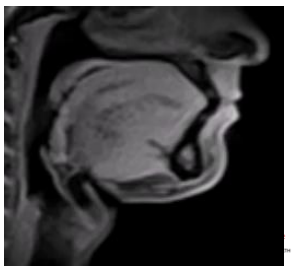
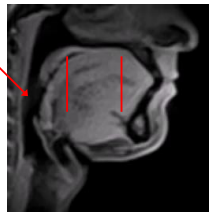


Tongue = Muscular Hydrostat



4

Tongue in Speech and Swallowing



Tongue Anterior/Body:
- Articulation
- Bolus Manipulation
- Bolus propulsion

Tongue Body/Posterior:
- Bolus propulsion
- Base of tongue retraction

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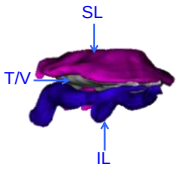
Intrinsic Tongue Muscles

- Superior Longitudinal
  - Tongue tip up
- Inferior Longitudinal
  - Tongue tip down
- Transverse
  - Narrow/Elongate
- Vertical
  - Flattens/Widens



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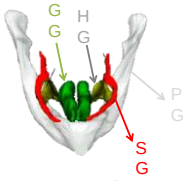
Extrinsic Tongue Muscles

- Genioglossus
  - Protrusion
- Styloglossus
  - Retrusion/Elevation
- Hyoglossus
  - Retrusion/Depression
- Palatoglossus
  - Floor elevation



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Innervation of the Tongue

Sensory	Motor
• Anterior 2/3 (general sensory) – CNV (Mandibular Branch) • Anterior 2/3 (special sensory-taste) – CNVII (Chorda Tympani) • Posterior 1/3 (general and special sensory-taste) – CNIX • Posterior Tongue (general sensory) – CNX	• CNX (pharyngeal branch) – Palatoglossus • CNXII – Hypoglossal

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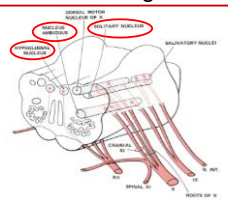
Neural Control of Tongue in Swallowing



- Retruder/protruder hypoglossal motoneurons modulated by swallowing rhythm.
- Retruder motoneurons closest to NTS begin swallowing activation.
- Protruder motoneurons (ventral brainstem) close to nucleus ambiguus are then activated.

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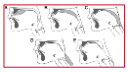
Role of the Tongue in Swallowing

- Oral bolus control- prevents premature loss of bolus into pharynx
- Bolus propulsion through the oral cavity and into the pharynx- sequential contact of oral tongue against hard palate generating pressure along the bolus
- Clears the oral cavity of residue
- Important role in mastication
- Base of tongue moves posteriorly to contact the posterior pharyngeal wall- creates pressure on the bolus in the pharynx
- Ensures clearance of material preventing residue within the vallecular space



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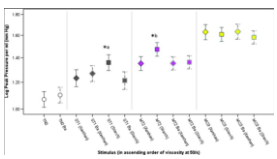
J Speech Lang Hear Res. 2019 Jan 30;62(1):22-33. doi: 10.1044/2018_JSLHR-S-18-0229.

Modulation of Tongue Pressure According to Liquid Flow Properties in Healthy Swallowing

Catriona M Steele [1,2], Melanie Peladeau-Pigeon [1], Carly A E Barbon [1,2], Brittany T Guida [1], Melanie S Tapson [1,2], Teresa J Valenzano [1,2], Ashley A Waito [1,2], Talia S Wolkin [1], Ben Hanson [1], Jane Jun-Xin Ong [1], Lisa M Dulcen [1]

- Tongue pressure patterns were measured in 38 healthy adults during swallowing with 4 IDDSI levels of progressively thicker liquid consistency
- Thicker liquids elicited significantly higher amplitudes of peak tongue pressure and a pattern of higher (i.e., steeper) pressure rise and decay slopes (change in pressure per unit time)
- No effects of barium or thickener type



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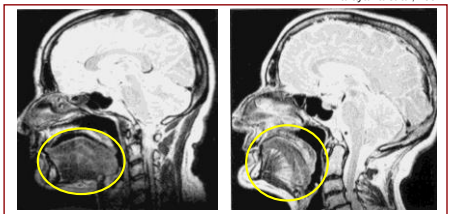
Sarcopenia- Head and Neck Muscles

- Reduction in tongue muscle fiber diameter

Nakayama et al., 1991



38 Yr Old Female | 81 Yr Old Female

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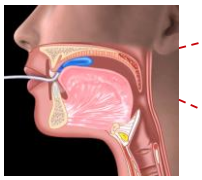
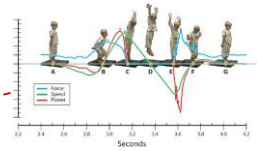
Oropharyngeal Functional Decline….



Maximum Isometric Lingual Pressure



Jumping Mechanography

Handgrip Strength

Buehring et al., 2013

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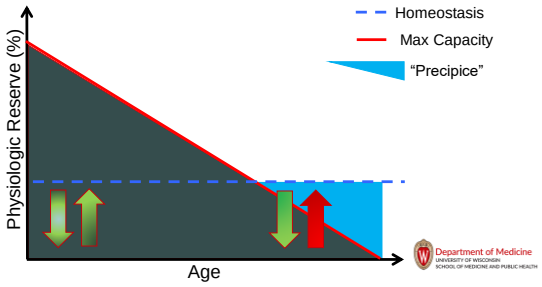
Homeostenosis



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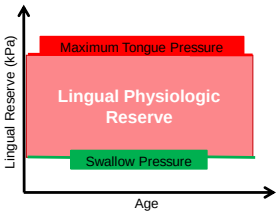
Lingual Physiologic Reserve: "Set Points"



Maximum Isometric Tongue Pressures:

Young (20-39yrs)	Middle (40-60yrs)	Old (>60yrs)
65.73 (12.95)	62.44 (12.21)	57.42 (12.97)

Note: Mean (SD); values listed in kPa

Swallowing Pressures:

Healthy Adults
15-25kPa

Lingual Physiologic Reserve:

Healthy Adult Average
~62-20kPa = ~42kPa

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Lingual Physiologic Reserve Considerations

- Older adults = lower maximum tongue pressures than younger, healthy adults.
- Females = lower maximum tongue pressures than men.

If saliva swallowing pressure remains constant, older adults and females presumably have less lingual reserve than their counterparts.

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Lingual Physiologic Reserve Considerations

- Does physical activity affect tongue composition/reserve?
  - 2016 study: Lack of physical activity in older adults associated with lower tongue strength.
  - 2018 study: Weightlifters had greater **tongue strength** than runners. Runners had greater **tongue endurance** than weightlifters.

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VanRavenhorst-Bell et al., 2016 & 2018

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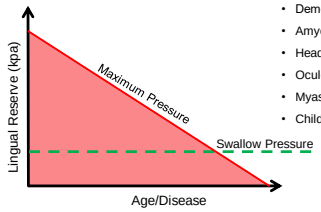
Homeostenosis of Lingual Reserve

Populations with Diminished Lingual Reserve:

- Healthy elderly
- Parkinson's Disease
- Stroke
- Dementia/Alzheimer's
- Amyotrophic Lateral Sclerosis
- Head and Neck Cancer
- Oculopharyngeal Muscular Dystrophy
- Myasthenia Gravis
- Children with MSDs



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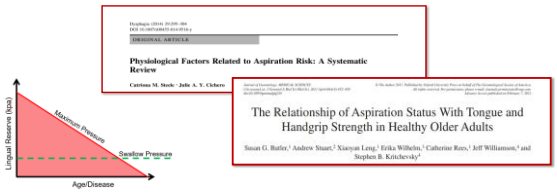
Homeostenosis of Lingual Reserve



Depletion Threshold: Maximum tongue pressure <40kPa associated with increased aspiration risk

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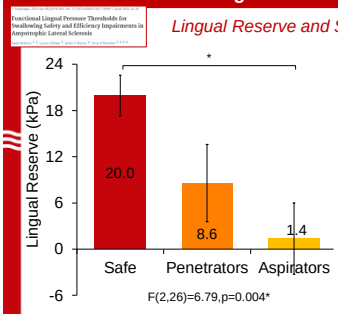
Homeostenosis of Lingual Reserve: ALS Clinical Example



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Low Lingual Pressure Generation

- Low lingual pressure generation is also associated with prolonged meal duration and decreased meal consumption.

> Clin Nutr. 2016 Oct;35(5):1078-83. doi: 10.1016/j.clnu.2015.08.001. Epub 2015 Aug 19.

The effect of tongue strength on meal consumption in long term care

Ashwini M Namasivayam [1], Catriona M Steele [2], Heather Keller [3]

Effects of Dining on Tongue Endurance and Swallowing-Related Outcomes

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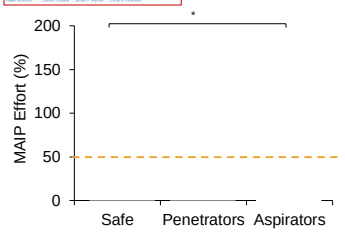
Homeostenosis of Lingual Reserve: ALS Clinical Example

Functional Lingual Pressure Thresholds for Swallowing Safety and Efficiency Impairments in Amyotrophic Lateral Sclerosis

Relative Effort for Swallowing:

Normative %Effort: <50%



F(2,26)=3.42, p=0.04

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Lingual Exercise Paradigms

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Targets for Lingual Exercise

Directly changing an aspect of functioning:
Isometric lingual strength (tongue pressure generation)
Isometric lingual endurance (tongue pressure generation)
Lingual coordination
Swallowing-related tongue pressures
Improved base of tongue retraction

Functional Outcomes Changed Indirectly:
Oropharyngeal residue
Safety (airway invasion)
Timing of swallow events

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Lingual Strengthening Tasks

Isometric Lingual Press	Isotonic Lingual Press	Tongue Pressure Strength and Accuracy Training	Endurance
"Press and hold" % of maximum varies across studies	Repeatedly apply pressure to bulb	**Strength:** Exceeding 80% of maximum pressure **Accuracy:** Achieving pressure targets randomly chosen between 25% and 85% maximum pressure	50% of maximum pressure, hold as long as possible

Tongue Pressure Profile Training	Power	Effortful Swallow with Lingual Resistance
Effortful or saliva swallows with slow release of pressure on tongue bulb	Produce /t/ repeatedly	Effortful swallow with lingual resistance using Iowa Oral Performance Instrument

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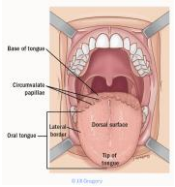
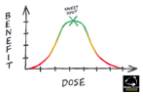
Exercise Dose Considerations

- Dose Parameters
  - # of repetitions per session
  - # of sessions
  - Duration of treatment
  - # of swallows (if any)
- Tongue location targeted
  - Front
  - Back
  - Base of tongue





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26

Exercise Principles


Review > Dysphagia. 2007 Jul;22(3):251-65. doi: 10.1007/s00455-006-9074-z. Epub 2007 Apr 25.

Strength-training exercise in dysphagia rehabilitation: principles, procedures, and directions for future research

Lori M Burkhead [3], Christine M Sapienza, John C Rosenbek

- Intensity
- Resistive loading- progressive
- Repetition and volume of practice
- Specificity
- Transference

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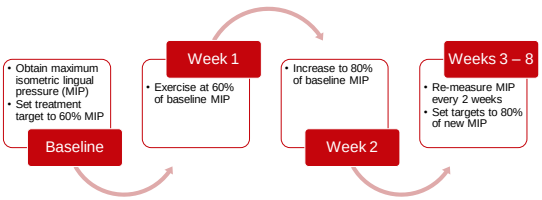
Lingual Strengthening: Protocol Example



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Exercise Principles


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Lori M Burkhead [1], Christine M Sapienza, John C Rosenbek

- Intensity ☑
- Resistive loading- progressive ☑
- Repetition and volume of practice ☑
- Specificity ☒
- Transference ?

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Lingual Strengthening Devices

Tongue Depressor

Swallow STRONG

Iowa Oral Performance Instrument

Tongueometer

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Iowa Oral Performance Instrument (IOPI)

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IOPI Medical, LLC

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Tongueometer Validation Against IOPI

A Pilot Assessment of Concurrent Validity and Comparative Reference Values for the Tongueometer Tongue Pressure Manometer

Tasia Gibbons,[a] Sophia Worden Abrams,[a] Nazia Mohsin,[a] Rebekah Guastella,[b] Stefania Oppedisano,[a] and Ashwini Namasivayam-MacDonald[a,c]

- Strong correlations between mean Tongueometer and IOPI measures
- Posterior maximum lingual pressures and maximum swallowing pressures statistically different between devices
  - Related to design of bulb?
- Anterior lingual pressures as measured with Tongueometer decreased with age but no difference in posterior lingual pressures

Krekeler, Hopkins, Tabangin, Roberts, Saadi, Martin-Harris, Rogus-Pulia: measures with Tongueometer were significantly lower than IOPI- indicates that reference values may need to be specific to device

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Swallow Strong Device

Age-Related Differences in Pressures Generated During Isometric Presses and Swallows by Healthy Adults

Comparison of Maximal Lingual Pressure Generation During Isometric Gross and Fine Sensorimotor Tasks in Healthy Adults

- 5 sensors- lateral, anterior, posterior, middle
- Mouthpiece custom-molded to hard palate
- Hectopascals instead of kilopascals
- Lower maximum lingual presses and swallowing-related pressures with advancing age
  - Sensor locations of swallowing pressure decline varied
- Decline with age greatest at front & back sensors
- Fine sensorimotor task= greater pressures; gross= faster pressures

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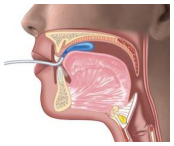
MIP Assessment: Positioning

Position 1

Bulb on Tongue

Position 2

Bulb on Palate



Namasivayam-MacDonald et al, 2017

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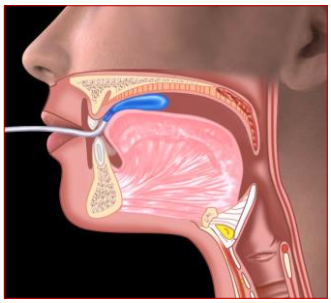

Anterior Lingual Press

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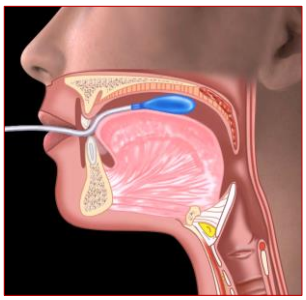

Posterior Lingual Press

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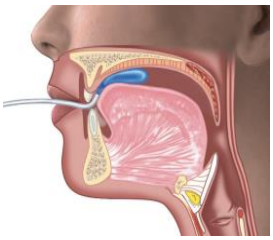
Saliva Swallow Assessment: Positioning

Bulb on Palate



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Saliva Swallow Assessment Tips: The "Do's"

- ☑ Give rest between trials as needed.
- ☑ Provide water to prevent dry mouth.
- ☑ Be mindful of extraneous movements.

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Saliva Swallow Assessment Tips: The "Don'ts"

- ☒ Record pressure value too early.
- ☒ Overdo it with the trials.

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Efficacy of Lingual Exercise as Dysphagia Treatment

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What Happens with Tongue Exercise in Rat Model?

- Increased force capacity with less fatigue
- Must keep exercising to maintain gains (detraining)
- Muscle fiber type transitions to more slowly contracting, fatigue resistant types
- Differential effects with type of exercise task
- Cross training: Some effect on vocalizations

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Populations Studied

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Recent Systematic Reviews

Sci Rep. 2022; 12: 10438.
Published online 2022 Jun 21. doi: 10.1038/s41598-022-14335-2
PMCID: PMC9213467
PMID: 35729179

Effects of tongue strengthening exercises on tongue muscle strength: a systematic review and meta-analysis of randomized controlled trials

Chien-Ju Lin,[1] Yu-Shan Lee,[1] Ching-Fang Hsu,[1] Shu-Jung Liu,[2] Jyun-Ying Li,[3] Yin-Lan Ho,[3] and Hsin-Hao Chen[#1,4,5]

Review | Open Access | Published: 14 October 2019

The Effect of Lingual Resistance Training Interventions on Adult Swallow Function: A Systematic Review

Sana Smaoui[✉], Amy Langridge & Catriona M. Steele

Dysphagia 35, 745–761 (2020) | Cite this article

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Published online 2022 Jun 21. doi: 10.1038/s41598-022-14335-2
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- Focused on randomized controlled trials comparing tongue strength obtained from maximal tongue elevation peak force in kilopascals
- 12 studies with 388 participants were included
  - 7 studies with healthy older adults
  - 5 with medical patients with cancer or stroke with or without dysphagia
- Pooled meta-analysis showed anterior and posterior tongue strength significantly higher compared to control group
  - Healthy adults: anterior tongue strength increase in all age groups- greatest in the those >65 years of age
- Meta-regression analysis revealed nonsignificant trend towards greater improvement in tongue strength with longer exercise duration

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Review | Open Access | Published: 14 October 2019

The Effect of Lingual Resistance Training Interventions on Adult Swallow Function: A Systematic Review

Sana Smaoui, Amy Langridge & Catriona M. Steele

Dysphagia 35, 745–761 (2020) | Cite this article

- Focused on evidence regarding effects of lingual resistance training on swallowing using Videofluoroscopic Swallowing Studies (VFSS) with adults
- 7 articles met inclusion criteria and underwent detailed review
- Heterogeneity in:
  - Population (stroke, brain injury, and healthy)
  - Training protocols
  - Outcome measures
- VFSS studies included a thin barium stimulus + another consistency
- Findings (no meta-analysis):
  - Temporal measures significantly improved in one study
  - Safety results mixed
  - Swallow efficiency improvements were limited to reductions in thin liquid barium residue in 2 studies

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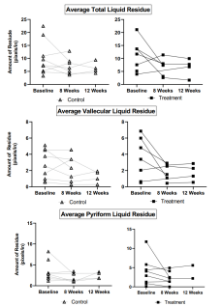
Dysphagia

https://doi.org/10.1007/s00455-023-10583-0

ORIGINAL ARTICLE

Effects of Device-Facilitated Lingual Strengthening Therapy on Dysphagia Related Outcomes in Patients Post-Stroke: A Randomized Controlled Trial

Brittany N. Krekeler[1,2,3] · Joanne Yee[4,5] · Atsuko Kurosu[3] · Fauzia Osman[6] · Rodolfo Peña-Chávez[7,8] · Glen Leverson[3] · Brittany Young[9] · Justin Sattin[6] · Molly Knigge[3] · Susan Thibeault[4,7] · Nicole Rogus-Pulia[4,5,6,7,10]



- 19 patients with acute post-stroke dysphagia (10 in control; 9 in treatment)
- Increase in lingual pressures at anterior and posterior sensors in treatment group and decrease in pressures in control group
- Decrease in liquid vallecular residue
- Large effects sizes but no significant change
- Significant improvement in Functional Oral Intake Scale (FOIS) scores in treatment group- improved bolus manipulation or improved confidence?

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Randomized Controlled Trial | Int J Environ Res Public Health. 2022 Jun 4;19(11):6878. doi: 10.3390/ijerph19116878.

Effects of Tongue-Strengthening Exercise on Tongue Strength Reserve and Detraining Effects among Healthy Adults: A Randomized Controlled Trial

Hsu-Ling Hsiao [1], Jiunn-Horng Lou [2], Chun-Chieh Wang [3,4], Yun-Ju Lai [3,5,6], Sheng-Jung Wu [7,8], Yueh-Juen Hsu [9]

- 102 healthy volunteers without dysphagia
- Randomized controlled trial
  - 50 to experimental group who underwent tongue exercise (tongue presses 30 minutes a day, 5 days per week, 8 weeks in duration- also a detraining period
  - 52 to control group
- Posterior tongue strength reserve of the experimental group was higher than the control group
- No significant detraining effects were observed on maximum pressures or swallowing-related pressures from 4 weeks after intervention

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Neuroreport. 2022 Jun 8;33(9):392-398. doi: 10.1097/WNR.0000000000001796. Epub 2022 May 11.

Alterations in white matter microstructural properties after lingual strength exercise in patients with dysphagia

Brittany N Krekeler [1,2,3], Jiancheng Hou [4,5], Veena A Nair [5], Vivek Prabhakaran [5], Nicole Rusche [3], Nicole Rogus-Pulia [2,3,6,7], JoAnne Robbins [3]

- Tongue exercise induced changes in white matter structural and functional properties in a small group of patients with heterogenous etiologies for dysphagia
- Increased cortical activity and plasticity following tongue exercise

Dysphagia. 2012 Sep;27(3):353-60. doi: 10.1007/s00455-011-9374-9. Epub 2011 Nov 11.

Brain activation during oral exercises used for dysphagia rehabilitation in healthy human subjects: a functional magnetic resonance imaging study

Emiko Ogura [1], Miwa Matsuyama, Tasuku K Goto, Yuko Nakamura, Kiyoshi Koyano

Randomized Controlled Trial | Neuroscience. 2013 Aug 29;246:1-12. doi: 10.1016/j.neuroscience.2013.04.040. Epub 2013 Apr 28.

Training-induced cortical plasticity compared between three tongue–training paradigms

M Kothari [1], P Svensson, J Jensen, A Kjaergaard, K Jeonghee, J F Nielsen, M Ghovanloo, L Basd Hansen

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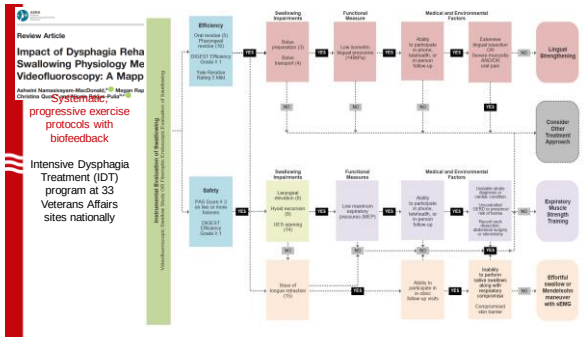

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Patient Population


Effects of exercise on swallowing and tongue strength in patients with oral and oropharyngeal cancer treated with primary radiotherapy with or without chemotherapy

- Patients who received oncologic treatment for head and neck cancer
- Randomized controlled trial
  - Tongue exercise plus traditional exercises versus traditional exercises alone (tongue range of motion and Mendelsohn)- 6 week duration
- No differences in tongue strength or oropharyngeal swallow efficiency (OPSE) within or between groups
- Patient adherence or treatment timing?

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Impact of Patient Adherence

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Adherence

- Defined as patient participation in prescribed treatment
- Participation in program may influence therapy dose received
- May also influence reproducibility of studies and findings


Patient Adherence to Dysphagia Recommendations: A Systematic Review


Dose in Exercise-Based Dysphagia Therapies: A Scoping Review

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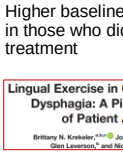
Adherence in Lingual Strengthening

- Even if "adherent", may not be successful at meeting target force threshold which can affect dose.
- No significant correlation between patient adherence and lingual pressure generation change
- Higher baseline lingual pressures in those who did not respond to treatment


Lingual Exercise in Older Veterans With Dysphagia: A Pilot Investigation of Patient Adherence

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Consider Role of Adherence… But With Caution

- Critical to consider health disparities and access to resources related to patient's ability to participate ("adhere") to treatment
- We must consider internal biases regarding who we think is most likely to adhere to recommendations or reasons for non-adherence
- Need to also consider modifications and supports that can help patients be successful in achieving therapeutic goals that are meaningful and well-aligned

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Questions and Discussion

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