ผลของการออกกำลังกายกล้ามเนื้อลิ้นด้วยอุปกรณ์ดัดแปลงจากไม้กดลิ้น ต่อแรงดันยกลิ้นในผู้ใหญ่สูงอายุและผู้สูงอายุ

เทียนฉาย ขจรวงศ์สถิต[1]*, ณัฐปภัสร์ บุญสวัสดิ์[2], ณัฐศาสตร์ อุณาศรี[3]

รับบทความ: 24 มิถุนายน 2569; ส่งแก้ไข: 2 กุมภาพันธ์ 2569; ตอบรับ: 9 กุมภาพันธ์ 2569

บทคัดย่อ

บทนำ : ภาวะมวลกล้ามเนื้อในช่องปากน้อย เป็นปัจจัยเสี่ยงที่สำคัญที่ทำให้เกิดภาวะกลืนลำบาก แม้ว่าเครื่อง Iowa Oral Performance Instrument (IOPI) จะได้รับการยอมรับว่าเป็นเครื่องมือมาตรฐานที่มีประสิทธิภาพสูงในการฟื้นฟูสมรรถภาพกล้ามเนื้อลิ้น แต่เนื่องจากตัวอุปกรณ์มีราคาสูงและจำเป็นต้องใช้บุคลากรเฉพาะทางในการบริการ ส่งผลให้เกิดข้อจำกัดในการเข้าถึงการรักษา การศึกษานี้จึงมีเป้าหมายเพื่อประเมินผลของอุปกรณ์บริหารกล้ามเนื้อลิ้นที่ดัดแปลงจากไม้กดลิ้นซึ่งได้รับการออกแบบโดยอาศัยกลไกทางกลศาสตร์ของระบบคานดีดคานงัดที่มีจุดหมุนคงที่ เพื่อควบคุมระดับแรงต้านให้มีความแม่นยำและเหมาะสมสำหรับการสร้างเสริมความแข็งแรงของกล้ามเนื้อลิ้นในผู้ใหญ่สูงอายุ

วัตถุประสงค์ : เพื่อประเมินประสิทธิศักย์ของเทคนิคการใช้อุปกรณ์ดัดแปลงจากไม้กดลิ้นที่ได้รับการปรับเทียบแรงต้านในการเพิ่มแรงยกลิ้นและความทนทานของกล้ามเนื้อยกลิ้น

วิธีดำเนินการวิจัย : การวิจัยครั้งนี้เป็นการศึกษาเชิงทดลองแบบสุ่มและมีกลุ่มควบคุมเพื่อทดสอบประสิทธิภาพที่เหนือกว่า ในกลุ่มตัวอย่างที่มีอายุตั้งแต่ 50 ปีขึ้นไป จำนวน 41 ราย (กลุ่มทดลอง 23 รายและกลุ่มควบคุม 18 ราย) โดยกลุ่มทดลองได้ฝึกบริหารลิ้นวันละ 2 ครั้งด้วยอุปกรณ์ดัดแปลงจากไม้กดลิ้นที่ได้รับการปรับเทียบแรงต้านที่ระดับร้อยละ 60 ของแรงยกลิ้นสูงสุด ต่อเนื่องเป็นเวลา 8 สัปดาห์ ประเมินผลลัพธ์หลักด้วยค่าแรงยกลิ้นสูงสุดและค่าความทนทานของกล้ามเนื้อยกลิ้น วัดผลโดยใช้เครื่อง IOPI และวิเคราะห์ข้อมูลทางสถิติโดยการเปรียบเทียบการเปลี่ยนแปลงจากค่าเริ่มต้น

ผลการศึกษา : ภายหลังการฝึกครบ 8 สัปดาห์ กลุ่มทดลองมีค่าความทนทานของกล้ามเนื้อยกลิ้นเพิ่มขึ้นสูงกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ (p = .008) ในส่วนของการพัฒนาของแรงยกลิ้นสูงสุดพบว่ากลุ่มทดลองมีค่าเฉลี่ยการเพิ่มขึ้นสูงกว่าที่ 3.35 kPa ขณะที่กลุ่มควบคุมที่มีการเพิ่มขึ้นเพียง 0.21 kPa อีกทั้งเมื่อเปรียบเทียบภายในกลุ่มทดลองเองยังพบว่าเพิ่มขึ้นอย่างมีแนวโน้มเข้าใกล้ระดับนัยสำคัญทางสถิติ (p = .054)

สรุป : เทคนิคการฝึกด้วยอุปกรณ์ดัดแปลงจากไม้กดลิ้นซึ่งได้รับการปรับเทียบแรงต้านมีประสิทธิผลในการเพิ่มความทนทานของกล้ามเนื้อลิ้นอย่างชัดเจน อุปกรณ์นี้จึงเป็นทางเลือกที่มีประสิทธิภาพ ราคาประหยัด และเหมาะสมสำหรับใช้ในการฟื้นฟูสมรรถภาพทางช่องปากด้วยตนเองเพื่อป้องกันภาวะช่องปากเปราะบางในผู้สูงอายุ

คำสำคัญ : การเพิ่มความแข็งแรงของลิ้น ไม้กดลิ้น ผู้ใหญ่สูงอายุ ภาวะกลืนลำบาก ภาวะเปราะบาง

[1] กลุ่มงานเวชกรรมฟื้นฟู โรงพยาบาลขอนแก่น จังหวัดขอนแก่น 40000.

[2] กลุ่มงานอายุรกรรม โรงพยาบาลขอนแก่น จังหวัดขอนแก่น 40000.

[3] กลุ่มงานโสต ศอ นาสิก โรงพยาบาลขอนแก่น จังหวัดขอนแก่น 40000.

*อีเมล: tianshine.k@gmail.com

Effect of a Wooden Tongue Depressor Technique Targeted Resistive Exercise in Enhancing Tongue Elevation Pressure for Older Adults: A Randomized Controlled Trial

Tianshine Kajohnwongsatit[1]*, Natthapapath Boonsawat[2], Natthasart Unasri[3]

Received: June 24, 2025; Received revision: February 2, 2026; Accepted: February 9, 2026

Abstract

Background: Oral sarcopenia is a significant risk factor for dysphagia. While the Iowa Oral Performance Instrument (IOPI) is effective for rehabilitation, its high cost limits accessibility. This study evaluated a low-cost wooden tongue depressor tool using a fixed-fulcrum lever system to improve tongue function in older adults.

Objective: To evaluate the efficacy of a calibrated wooden tongue depressor technique for enhancing tongue pressure and endurance.

Methods: A randomized controlled superiority trial was conducted with 41 participants aged 50 and older (intervention *n*=23, control *n*=18). The intervention group also performed twice-daily training for 8 weeks using a wooden tool calibrated to 60% of their maximum tongue pressure (MTP). Outcomes included MTP and endurance tongue pressure (ETP) measured by IOPI. Statistical analysis compared change scores from baseline.

Results: After 8 weeks, the intervention group showed significantly greater ETP improvement than the control group (p = .008). Mean MTP improvement in the intervention group (3.35 kPa) was higher than in the control group (0.21 kPa). Within-group improvement for the intervention group approached significance (p = .054).

Conclusion: The wooden tongue depressor technique effectively improves tongue endurance. This accessible, low-cost tool provides a practical alternative for home-based rehabilitation to prevent the progression of oral frailty.

Keywords: tongue strengthening, wooden tongue depressor, older adult, dysphagia, frailty

[1] Department of Physical Medicine and Rehabilitation, Khon Kaen Hospital, Khon Kaen, 40000, Thailand.

[2] Department of Medicine, Khon Kaen Hospital, Khon Kaen, 40000, Thailand.

[3] Department of Otolaryngology, Khon Kaen Hospital, Khon Kaen, 40000, Thailand.

*Correspondence E-mail: tianshine.k@gmail.com

Introduction

Swallowing is a complex sequence of actions that takes place within the confined anatomy of the head and neck, relying on coordinated function of multiple systems, including motor control, sensory input, reflexes, and cognitive processing.[1-2] The goal of this intricate process is to form a cohesive bolus and efficiently transport it to the esophagus while preventing aspiration or misdirection into the airway.[1-4] A dysfunction in any of these components can result in dysphagia. Among its diverse causes, sarcopenia is one of commons.[5-6] As a consequence, safe and effective swallowing depends on adequate muscle strength, range of motion, and coordination. Management strategies for dysphagia typically involve either compensatory techniques or rehabilitative training. These may include postural adjustments, dietary modifications, sensory stimulation, and targeted exercises to strengthen the oropharyngeal muscles.[6–10]

The increasing prevalence of age-related conditions presents a significant challenge. The global aging population is growing rapidly, with the elderly population expected to more than double in the next 30 years.[11] This demographic shift is accompanied by an increase in age-related frailty, including oral sarcopenia.[2, 11-12] Such a decline in oral muscle functions can lead to difficulties in swallowing and speech. The consequences negatively impact nutritional intake, cognitive function, and overall quality of life.[13-14] In all various frailty-related factors, reduced tongue function is a significant contributor to dysphagia.[15] Therefore, strengthening the tongue is one key therapeutic approach.

This focus on tongue strengthening is based on the tongue's crucial role throughout most of the swallowing process. In the oral phase, it manages the food bolus during mastication and propulsion. The tongue also aids in generating the pressure needed to move the bolus through the pharynx during the pharyngeal phase.[16] Tongue elevation pressure is typically generated by the upward movement of the tongue against the hard palate, a critical mechanism for bolus formation and for generating the force necessary to initiate upper esophageal sphincter (UES) opening.[17-18]

Maximum Tongue Pressure (MTP) measures the peak strength of the tongue, whereas Endurance Tongue Pressure (ETP) reflects the ability to sustain force over time. Both parameters typically decline with age.[14] Hara et al. identified a significant association between tongue pressure and chewing ability in healthy individuals;[19] furthermore, several studies have linked higher MTP with improved swallowing outcomes.[20-22] Similarly, ETP has been found to positively influence chewing efficiency and meal consumption, though these results require further investigation.[23] Yen-Fang Chou et al. suggest that both metrics play a vital role in swallowing function, noting that ETP may be even more sensitive than MTP for detecting oropharyngeal dysphagia among community-dwelling older adults.[24] Collectively, this evidence indicates that MTP and ETP are essential components of

swallowing physiology and serve as reliable indicators for identifying dysphagia.

Preventive measures are most effective when implemented early. Hong HL et al. recommend beginning interventions at age 50, when early signs of oral frailty typically emerge.[25] Consequently, evaluating and strengthening tongue function is essential for the early prevention of dysphagia.

Variety of effective methods for increasing tongue pressure ranging from using medical-grade equipment to home-based tools, have been widely used.[26–30] A systematic review confirmed that tongue-strengthening exercises effectively increase pressure, with significant improvements typically observed after an 8-week intervention.[27] a resistive load of approximately 60% MTP is commonly employed, aligning with general skeletal muscle training principles.[26] Issues related to their cost, accessibility, and ease of use remains significant barriers to widespread implementation, especially in limited-resource areas.[31] The wooden tongue depressor technique is a simple, low-cost method that requires minimal resources. Despite its practicality and potential advantages, this technique has yet to be assessed using objective outcome measures. More research is needed to validate its effectiveness and determine its role in clinical and home-based rehabilitation programs.

The primary aim of this study was to evaluate the efficacy of a calibrated wooden tongue depressor as a low-cost tool for lingual strengthening in older adults. We conducted a randomized superiority trial to compare this intervention against a standard oropharyngeal exercise control group. The null hypothesis was that there would be no difference in the improvement of MTP or ETP between the two groups.

Objective

This study aims to evaluate the effectiveness of the wooden tongue depressor technique in improving MTP and ETP among older adults through a randomized controlled trial. The findings are expected to support the integration of tongue-strengthening exercises into clinical practice as a practical, accessible strategy for managing frailty and enhancing quality of life.

Methods

Study Design

A two-parallel-group randomized controlled superiority trial was conducted following the CONSORT guidelines at a regional health center during January-May, 2025. Ethical approval was obtained from the institutional review board prior to research conduction. IRB approval number: KEF67036. This study was registered in the Thai Clinical Trials Registry under the code TCTR20250610003: https://thaiclinicaltrials.org/export/pdf/TCTR20250610003. Registered on June 10, 2025.

Participants

Inclusion criteria consisted of adults aged 50 years and older with no prior diagnosis of dysphagia or motor deficits. By including both late middle-aged and older adults, the study aims to assess the efficacy of the intervention as a preventive measure before the onset of significant age-related swallowing impairment.

Conversely, exclusion criteria included moderate to severe dementia, an inability to follow the exercise protocol, or significant communication difficulties. Recruitment was conducted between January and February 2025, and informed consent was obtained from all participants prior to their enrollment.

Sample size

A clinically meaningful difference was defined as a 10% increase in MTP from baseline.[32] Given a reported average baseline MTP of 49.5 kilopascals (kPa),[33] a 10% improvement corresponds to an absolute increase of approximately 5 kPa. Using a two-tailed test with an alpha level of 0.05 and a power of 80%, the minimum required sample sizes for the control and intervention groups were 15 and 19 participants, respectively. To account for a potential 20% dropout rate, the final allocation target was at least 18 participants for the control group and 23 for the intervention group.

Randomization and Blinding

Participants were randomized (1:1) via a computer-generated sequence in Microsoft Excel 2010. Allocation concealment was maintained by an independent third-party coordinator who collected baseline demographics before assigning participants to groups. To ensure a double-blind protocol, both the primary assessor (utilizing the IOPI) and the data analyst remained unaware of group identities until the final analysis. While participants were aware of their tasks, they remained blinded to the study hypotheses to minimize expectation bias.

Intervention Standard Care and Intervention

All participants performed a standard oropharyngeal home program including neck stretches, mouth-opening, cheek puffing, and chin-tuck-against-resistance (CTAR). The intervention group additionally Completed a twice-daily tongue-strengthening regimen for eight weeks using a custom wooden tongue depressor.

Tongue Strengthening Instrumentation

To provide a quantifiable and reproducible resistive load, the tool was designed as a fixed-fulcrum lever system (15 cm in total length). A variable stack of medical-grade wooden depressors is secured at the exact mid-length (7.5 cm) to act as the fulcrum, creating a mechanical gap at the anterior end. Resistance is generated by the elastic modulus of the wood. As the participant presses the arms together, the material provides counter-pressure until the gap is closed. This ensures that the resistance is a direct result of the stack's height and stiffness. Also, the tongue must exert the full 60% MTP to successfully close the tool. Figure 1 shows a wooden tongue depressor tool.

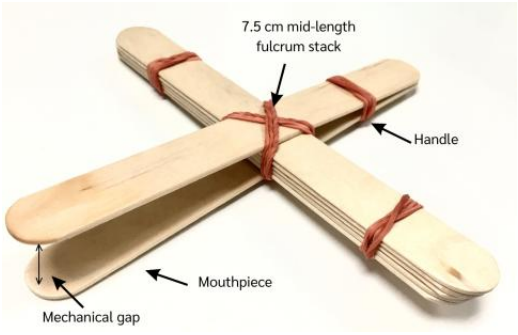


Fig. 1 Structural design and components of the calibrated wooden tongue depressor tool.

Calibration Protocol

To ensure therapeutic dosing, the tool was individually calibrated for each participant using the IOPI. The air-filled IOPI bulb was positioned on the superior surface of the upper lever arm tip, and a vertical downward force was applied until the anterior tips of both arms achieved full contact. The height of the central fulcrum stack was systematically adjusted by adding or removing depressors until the force required to close the device's gap reached the specific target threshold of 60% MTP.

Training Protocol and Dosage

To perform the exercise, participants positioned the distal end of the calibrated tool between the hard palate and the dorsal surface of the anterior tongue. A vertical upward force was applied against the inferior lever arm until the arms achieved full contact; this tactile cue signified that the 60% MTP resistance threshold had been met.

Once contact was established, participants performed an isometric hold, maintaining tip-to-tip closure for as long as possible. The duration of each hold was measured in seconds and documented in a standardized daily exercise log to track progress and adherence. The protocol permitted up to two sessions per day. To prevent excessive lingual fatigue and ensure safety, participants were encouraged to incorporate self-paced rest intervals between repetitions, allowing for recovery without compromising task intensity.

Regarding equipment and hygiene, each participant received eight identical tools, with instructions to use one tool per week. Following each session, the device was washed with water and placed in a clean rack to air-dry completely. Figure 2 shows how to perform tongue strengthening exercise using the tools.

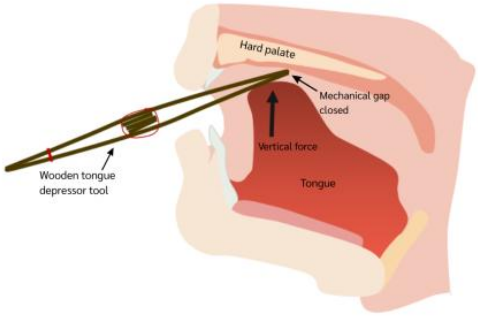


Fig. 2 Lingual exercise technique and participant positioning.

An independent researcher blinded to the group allocations conducted weekly randomized reminder calls to verify exercise adherence and screen for adverse events.

Outcome Measurements

MTP and ETP were assessed at baseline and week 8 using the IOPI. MTP was recorded in kPa, choosing the highest value from three trials. ETP was measured as the duration in seconds that participants could sustain 60% of their MTP. To minimize fatigue, ETP testing was limited to one trial per session.

Statistical Analysis

All analyses followed the intention-to-treat principle, including all participants according to their original group allocation.

Normality and Descriptive Statistics

The distribution of continuous data (MTP and ETP) was assessed for normality using the Shapiro-Wilk test. Descriptive statistics are presented as means and standard deviations (SD) for normally distributed data, and as medians and interquartile ranges (IQR) for non-normally distributed data. Categorical variables, such as sex and the presence of underlying diseases, are presented as frequencies and percentages.

Within-Group Comparisons

To evaluate the change from baseline to the 8-week endpoint within each group, a dependent t-test was used for normally distributed variables. For non-normally distributed variables, the Wilcoxon signed-rank test was employed.

Between-Group Comparisons

Baseline demographic characteristics and baseline tongue pressures were compared between the intervention and control groups using the independent t-test, the Mann-Whitney U test, and the Chi-square test.

The difference in improvement between groups was conducted by comparing the "change scores" (Week 8 value minus Baseline value). As a superiority trial, the null hypothesis was that there would be no difference in improvement between groups. Between-group comparisons of MTP and ETP improvements were conducted using the independent t-test or the Mann-Whitney U test, depending on the results of normality testing.
A significance level of $p < .05$ was considered statistically significant for all analyses.

Results

A total of 50 individuals were screened for eligibility. Of these, 9 were excluded: 5 did not meet inclusion criteria, 2 declined to participate, and 2 were excluded due to severe dementia. The remaining 41 participants were randomized into the intervention group (n = 23) or the control group (n = 18). All participants reported completed at least 80% of the prescribed session. There was no loss to follow-up or discontinuation; all 41 participants completed their allocated protocols and were included in the final analysis (Figure 3).

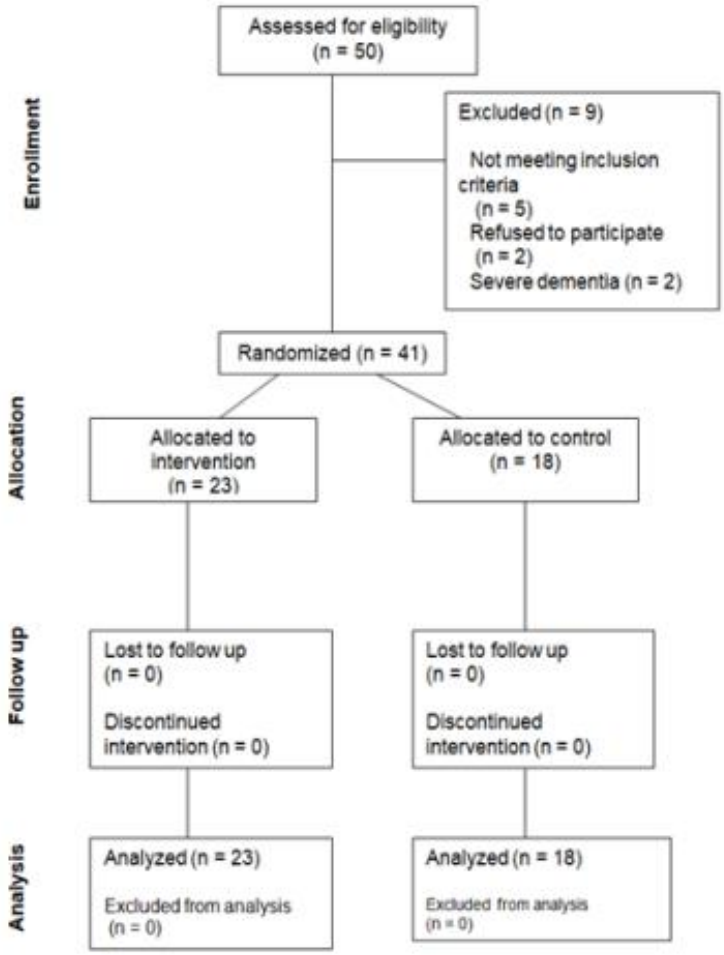


Fig. 3 Flow diagram of participant recruitment, allocation, and follow-up.

Baseline Characteristics

As detailed in Table 1, the groups demonstrated high baseline comparability. There were no significant differences in age (p = .862), BMI (p = .367), or sex distribution (p = .834). Similarly, baseline lingual metrics showed no significant differences between the control and intervention groups for MTP (39.72 ±16.87 kPa vs. 43.17 ± 13.97 kP; p = .478) or ETP (Median 6.39 s vs. 5.78 s; p = .968).

Within-Group Comparisons

Within-group changes over the 8-week period are summarized in Table 2. The control group exhibited no significant changes in MTP (p = .704) or ETP (p = .097). In contrast, the intervention group demonstrated a significant improvement in ETP (p = .043), while the increase in MTP approached statistical significance (p = .054).

Between-Group Comparisons

Comparison of improvements between groups revealed a significantly greater increase in ETP for the intervention group (Median 7.25 s, IQR: 2.00–27.32) compared to the control group (Median 1.26 s, IQR: 0.00–2.94; p = .008). While the intervention group showed a higher mean improvement in MTP (3.35 ± 4.71 kPa) than the control group (0.21 ± 2.35 kPa), this difference did not reach statistical significance (p = .106).

Safety and Tolerability

Regarding safety, 87% of participants (*n* = 20) in the intervention group reported mild lingual discomfort or muscle fatigue during the first two weeks. These symptoms were transient and resolved spontaneously as the study progressed. No serious adverse events were reported.

Discussion

Baseline Characteristics and Oral Pre-frailty

In healthy individuals, normative lingual metrics typically exceed 30 kPa for MTP and 10 seconds for ETP.[34] Our participants exhibited preserved strength (approx. 40 kPa) but reduced endurance (approx. 6 seconds), a profile consistent with pre-oral frailty who just beginning to experience functional decline. This profile aligns with the absence of reported dysphagia symptoms. Building a "functional reserve" may prevent or delay the progression to clinical oral frailty, which is associated with adverse outcomes such as malnutrition, aspiration, and cognitive decline.[13-14, 35-36]

Our study found a significant improvement in ETP (p = .008) and a strong trend toward increased MTP (p = .054). Specifically, the intervention group achieved a mean increase of 3.35 kPa, whereas the control group improved by only 0.21 kPa. This difference shows that the wooden tongue depressor tool has a real effect on tongue strength. While a larger cohort may be needed to reach statistical significance for peak strength, these results suggest that the tool is useful for improving both endurance and strength in the early stages of oral frailty.

These outcomes are best understood when compared to current common interventions, particularly in terms of physiological load, feedback mechanisms and accessibility.

Similarities in Physiological Load

The protocol utilized a 60% MTP resistive load, aligning with standard IOPI-based regimens.[29,37-38] This intensity adheres to principles of hypertrophy by requiring the tongue to exert force against a pre-calibrated resistance, while optimizing strength gains without inducing excessive muscle.[29]

Differences in Feedback Mechanisms

Unlike the digital visual biofeedback of the IOPI, our tool provides mechanical tactile feedback. The "all-or-nothing" physical contact of the lever arms ensures every repetition meets the target threshold, offering an objective alternative to subjective manual resistance.

Device Cost and Accessibility

While the IOPI is often restricted in some clinical settings due to its cost,[31] our tool uses medical-grade wooden depressors. The simplicity of the tool, combined with weekly randomized reminder calls, contributed to high participant adherence.[39-40] This makes the protocol highly accessible for home-based rehabilitation and resource-limited settings without sacrificing loading precision or the biofeedback.

Limitations and Future research

This study has several limitations. First, including participants aged 50 and older resulted in a healthier cohort than a typical "frail" population, which may limit the generalizability of results to patients with established dysphagia. Second, the 8-week duration may be the minimum threshold required to observe

significant MTP gains.[29] Finally, while self-reported logs are susceptible to bias, they remain a pragmatic necessity for home-based protocols. The high frequency of reported muscle fatigue suggests strong participant adherence.

Future research should explore the differential effects of this technique on pre-frail versus frail individuals to better tailor interventions. Larger sample sizes and longer training durations can help clarifying the timeframe needed for MTP gains. Finally, incorporating functional outcome measures, such as Modified Barium Swallow studies or aspiration rates, would provide a more comprehensive understanding of the intervention's long-term impact on swallowing safety.

Conclusion

The wooden tongue depressor technique tends to improve tongue endurance pressure in older adults. Its ease of implementation and accessibility suggest its potential as a practical tool for swallowing rehabilitation. Future studies should evaluate its long-term benefits and applicability in frail populations

Table 1 Participant Demographics Data

	Control Group (n = 18)	Intervention Group (n = 23)	*p*-value
Age (years)[1]	67.94 ± 12.77	68.57 ± 9.97	.862[a]
BMI (kg/m²)[1]	22.65 ± 2.89	23.77 ± 4.51	.367[a]
Sex (M/F), *n*	4/14	6/18	.834[b]
Baseline MTP (kPa)[1]	39.72 ± 16.87	43.17 ± 13.97	.478[a]
Baseline ETP (sec)[2]	6.39 [2.95, 18.25]	5.78 [5.05, 15.02]	.968[c]
Underlying disease (*n*)	Deep vein thrombosis (1) Osteoporosis (1) Asthma (1)	Benign prostate hyperplasia (2) Rheumatoid arthritis (1) Colon cancer (1) Gout (1)	

[1] Mean±SD, [2]Median [IQR]

[a]Independent t-test, [b]Chi-square test, [c]Mann-Whitney U test.

BMI, body mass index; M, male; F, female; *n,* number; MTP, maximum tongue pressure; ETP, endurance tongue pressure

Table 2 Outcomes Comparisons

	Group	Mean/Median Change	Within-Group p^a	Between-Group p^b
MTP (kPa)[1]	Control	0.21 ± 2.35	.704	.106
	Intervention	3.35 ± 4.71	.054	
ETP (sec)[2]	Control	1.26 [0.00,2.94]	.097	.008*
	Intervention	7.25 [2.00,27.32]	.043*	

[1] Mean±SD, [2]Median [IQR]

[a]Dependent t-test (MTP) or Wilcoxon Signed-Rank test (ETP) for within-group comparison. [b]Independent t-test (MTP) or Mann-Whitney U test (ETP) for between-group comparison of change.

*Statistically significant ($p < .05$)

MTP, maximum tongue pressure; ETP, endurance tongue pressure; kPa, kilopascals; sec, seconds.

Conflict of Interest Declaration

The authors confirm that there is no conflict of interest related to the manuscript.

Funding

This study was self-funded by the researchers and received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Generative AI Declaration

There was no use of AI in this research beyond language and grammar improvement. Authors take full responsibility for the integrity of the published work.

References

1. Costa MMB. Neural control of swallowing. Arq Gastroenterol. 2018;55Suppl 1(Suppl 1):61–75.
2. Christensen K, Doblhammer G, Rau R, Vaupel JW. Ageing populations: the challenges ahead. Lancet. 2009 3;374(9696):1196–208.
3. Panara K, Ramezanpour Ahangar E, Padalia D. Physiology, Swallowing. In: StatPearls. Treasure Island (FL): StatPearls Publishing; 2023.
4. Logemann JA, Larsen K. Oropharyngeal dysphagia: pathophysiology and diagnosis for the anniversary issue of Diseases of the Esophagus. Dis Esophagus. 2012;25(4):299–304.
5. Panebianco M, Marchese-Ragona R, Masiero S, Restivo DA. Dysphagia in neurological diseases: a literature review. Neurol Sci. 2020 ;41(11):3067–73.
6. Rivelsrud MC, Hartelius L, Bergström L, Løvstad M, Speyer R. Prevalence of Oropharyngeal Dysphagia in Adults in Different Healthcare Settings: A Systematic Review and Meta-analyses. Dysphagia. 2023;38(1):76–121.
7. Bisch EM, Logemann JA, Rademaker AW, Kahrilas PJ, Lazarus CL. Pharyngeal effects of bolus volume, viscosity, and temperature in patients with dysphagia resulting from neurologic impairment and in normal subjects. J Speech Hear Res. 1994;37(5):1041–59.

8. Welch MV, Logemann JA, Rademaker AW, Kahrilas PJ. Changes in pharyngeal dimensions effected by chin tuck. Arch Phys Med Rehabil. 1993;74(2):178–81.
9. Raut VV, McKee GJ, Johnston BT. Effect of bolus consistency on swallowing--does altering consistency help? Eur Arch Otorhinolaryngol. 2001;258(1):49–53.
10. Logemann JA. Dysphagia: evaluation and treatment. Folia Phoniatr Logop. 1995;47(3):140–64.
11. United Nations Publications. World Population Prospects 2019: Demographic Profiles. 2020.
12. Yuan S, Larsson SC. Epidemiology of sarcopenia: Prevalence, risk factors, and consequences. Metabolism. 2023; 144:155533.
13. Yitbarek GY, Alty J, Lawler K, Goldberg LR. Current evidence on the association of tongue strength with cognitive decline in older adults and the known risk factors of frailty, sarcopenia and nutritional health: a scoping review protocol. BMJ Open. 2023-28;13(10):e076005.
14. Tanaka T, Takahashi K, Hirano H, Kikutani T, Watanabe Y, Ohara Y, et al. Oral Frailty as a Risk Factor for Physical Frailty and Mortality in Community-Dwelling Elderly. J Gerontol A Biol Sci Med Sci. 2018 10;73(12):1661–7.
15. Satake A, Kobayashi W, Tamura Y, Oyama T, Fukuta H, Inui A, et al. Effects of oral environment on frailty: particular relevance of tongue pressure. Clin Interv Aging. 2019 12; 14:1643–8.
16. Ross CF, Laurence-Chasen JD, Li P, Orsbon C, Hatsopoulos NG. Biomechanical and Cortical Control of Tongue Movements During Chewing and Swallowing. Dysphagia. 2024;39(1):1–32.
17. Ono T, Hori K, Nokubi T. Pattern of tongue pressure on hard palate during swallowing. Dysphagia. 2004 Autumn;19(4):259–64.
18. Hori K, Taniguchi H, Hayashi H, Magara J, Minagi Y, Li Q, et al. Role of tongue pressure production in oropharyngeal swallow biomechanics. Physiol Rep. 2013;1(6):e00167.
19. Hara K, Tohara H, Kenichiro K, Yamaguchi K, Ariya C, Yoshimi K, et al. Association between tongue muscle strength and masticatory muscle strength. J Oral Rehabil. 2019;46(2):134–9.
20. Hiraoka A, Yoshikawa M, Nakamori M, Hosomi N, Nagasaki T, Mori T, et al. Maximum Tongue Pressure is Associated with Swallowing Dysfunction in ALS Patients. Dysphagia. 2017;32(4):542–7.
21. Minagi Y, Ono T, Hori K, Fujiwara S, Tokuda Y, Murakami K, et al. Relationships between dysphagia and tongue pressure during swallowing in Parkinson's disease patients. J Oral Rehabil. 2018;45(6):459–66.
22. Konaka K, Kondo J, Hirota N, Tamine K, Hori K, Ono T, et al. Relationship between tongue pressure and dysphagia in stroke patients. Eur Neurol. 2010-13;64(2):101–7.
23. Mozzanica F, Pizzorni N, Ginocchio D, Feroldi S, Bianchi F, Castellari M, et al. Tongue Strength and Endurance in

Patients with Parkinson's Disease: Association with Swallowing, Oral Phase Efficiency, Meal, Diet Type and Malnutrition Risk. Dysphagia [Internet]. 2025 3; Available from: http://dx.doi.org/10.1007/s00455-025-10902-7

24. Chou YF, Sung CM, Chu YH, Chiang KJ, Chen R, Banda KJ, et al. Accuracy of tongue strength, endurance, and pressure using Iowa oral performance instrument and predictors of dysphagia in community-dwelling older adults: a cross-sectional study. BMC Geriatr. 2025 24;25(1):194.
25. Hong HL, Kim NH. Determining the Onset Age for Early Intervention of Oral Frailty. J Dent Hyg Sci. 2024 31;24(1):1–8.
26. Burkhead LM, Sapienza CM, Rosenbek JC. Strength-training exercise in dysphagia rehabilitation: principles, procedures, and directions for future research. Dysphagia. 2007;22(3):251–65.
27. Nurfatul Jannah S, Syahrul S, Kadar K. The effectiveness of tongue strengthening exercise in increasing tongue strength among older people with dysphagia: A systematic review. Health Sciences Review. 2022 1; 4:100047.
28. Lin CJ, Lee YS, Hsu CF, Liu SJ, Li JY, Ho YL, et al. Effects of tongue strengthening exercises on tongue muscle strength: a systematic review and meta-analysis of randomized controlled trials. Sci Rep. 2022 21;12(1):10438.
29. Van den Steen L, Vanderwegen J, Guns C, Elen R, De Bodt M, Van Nuffelen G. Tongue-Strengthening Exercises in Healthy Older Adults: Does Exercise Load Matter? A Randomized Controlled Trial. Dysphagia. 2019;34(3):315–24.
30. Iyota K, Mizutani S, Kishimoto H, Oku S, Tani A, Yatsugi H, et al. Effect of Isometric Tongue Lifting Exercise on Oral Function, Physical Function, and Body Composition in Community-Dwelling Older Individuals: A Pilot Study. Gerontology. 2022; 68(6):644–54.
31. Krekeler BN, Broadfoot CK, Johnson S, Connor NP, Rogus-Pulia N. Correction to: Patient Adherence to Dysphagia Recommendations: A Systematic Review. Dysphagia. 2018 ;33(4):589–91.
32. Aoki Y, Kabuto S, Ozeki Y, Tanaka T, Ota K. The effect of tongue pressure strengthening exercise for dysphagic patients. Jpn J Compr Rehabil Sci. 2015;6:129–36.
33. Robbins J, Levine R, Wood J, Roecker EB, Luschei E. Age effects on lingual pressure generation as a risk factor for dysphagia. J Gerontol A Biol Sci Med Sci. 1995 ;50(5):M257–62.
34. Normal Values [Internet]. IOPI Medical. IOPI Medical LLC; 2017 [cited 2026 Jan 14]. Available from: https://iopimedical.com/normal-values/
35. World Health Organization. WHO clinical consortium on healthy ageing 2021: report of consortium meeting held virtually, 5-6 November 2021. World Health Organization; 2022. 70 p.
36. Tanaka T, Hirano H, Ikebe K, Ueda T, Iwasaki M, Minakuchi S, et al. Consensus statement on "Oral frailty" from the Japan Geriatrics Society, the Japanese Society of

Gerodontology, and the Japanese Association on Sarcopenia and Frailty. Geriatr Gerontol Int. 2024 ;24(11):1111–9.

37. Robbins J, Gangnon RE, Theis SM, Kays SA, Hewitt AL, Hind JA. The effects of lingual exercise on swallowing in older adults. J Am Geriatr Soc. 2005 ;53(9):1483–9.
38. Yano J, Yamamoto-Shimizu S, Yokoyama T, Kumakura I, Hanayama K, Tsubahara A. Effects of anterior tongue strengthening exercises on posterior tongue strength in healthy young adults. Arch Oral Biol. 2019 ;98:238–42.
39. Kraemer WJ, Ratamess NA. Fundamentals of resistance training: progression and exercise prescription. Med Sci Sports Exerc. 2004;36(4):674–88.
40. Collado-Mateo D, Lavín-Pérez AM, Peñacoba C, Del Coso J, Leyton-Román M, Luque-Casado A, et al. Key Factors Associated with Adherence to Physical Exercise in Patients with Chronic Diseases and Older Adults: An Umbrella Review. Int J Environ Res Public Health [Internet]. 2021 19;18(4). Available from: http://dx.doi.org/10.3390/ijerph18042023