

IoT-Based Oral Exercise for the Elderly: Effects on Tongue Pressure, Chewing Function, and Quality of Life

Khusnul Hikmatul Asar^{1*}, & Chantika Aditya Pramswari²

^{1*}Poltekkes Kemenkes Padang, Indonesia, ²Poltekkes Kemenkes Padang, Indonesia

*Co e-mail: khusnulhikmatul@gmail.com¹

Article Information

Received: September 09, 2026

Revised: September 24, 2026

Online: September 27, 2026

Keywords

Internet of Things, Oral Exercise,
Oral Frailty

ABSTRACT

Age-related decline in tongue strength and chewing function, collectively described as oral frailty, is associated with malnutrition, dysphagia, and reduced oral health-related quality of life among older adults, yet adherence to conventional unsupervised oral exercise programs remains a persistent barrier to their effectiveness. This study evaluated the effects of an Internet of Things (IoT)-based oral exercise program, incorporating a sensor-embedded mouthpiece with real-time biofeedback and remote compliance monitoring, on tongue pressure, chewing function, and oral health-related quality of life among community-dwelling elderly adults, compared against conventional printed oral exercise instructions. A single-blind, parallel-group randomized controlled trial was conducted among 64 community-dwelling adults aged 65 years and older, randomized to an 8-week IoT-based program ($n = 32$) or conventional printed instructions ($n = 32$). Fifty-nine participants (30 IoT, 29 control) completed the intervention. The IoT group showed significantly greater improvement across all outcomes: tongue pressure increased by 8.2 kPa versus 3.3 kPa ($t = 6.84$, $p < 0.001$, $d = 1.71$); chewing function improved by 14.6 versus 5.3 points ($t = 5.92$, $p < 0.001$, $d = 1.48$); and OHIP-14 score decreased by 7.3 versus 3.1 points ($t = 5.15$, $p < 0.001$, $d = 1.29$). Mean device compliance was 87.4%, significantly correlated with tongue pressure improvement ($r = 0.59$, $p < 0.001$). These findings support integrating IoT-based digital health technology into oral frailty prevention programs for community-dwelling older adults.

INTRODUCTION

Age-related decline in oral motor function, encompassing reduced tongue strength, impaired chewing (masticatory) function, and diminished swallowing efficiency, has increasingly been recognized as a distinct clinical construct termed oral frailty, which is associated with subsequent physical frailty, malnutrition, and increased mortality risk among older adults (Kolle, Lewis, Lalonde, & Backman, 2023, as cited in Effects of synergistic tongue and chin resistance training on swallowing function, oral intake, and cognitive function in community-dwelling elderly individuals with frailty, 2025). Reduced tongue pressure specifically has been identified as a clinically meaningful predictor of swallowing dysfunction and aspiration risk, with tongue pressure during swallowing below approximately 10.32 kPa proposed as a cutoff for elevated aspiration pneumonia risk among hospitalized older adults with multiple comorbidities (A tongue resistance training program improves strength, endurance, and swallowing in frail older adults with mild cognitive impairment, 2025).

Oral exercise interventions, including tongue resistance training, chin tuck against resistance exercises, and gum-chewing exercises, have accumulated a substantial evidence base supporting their effectiveness in improving tongue pressure and chewing function among older adults. A recent systematic review and meta-analysis of 11 randomized controlled trials involving 734 participants found that oral exercise interventions significantly improved tongue-lip motor function, tongue pressure, chewing function, and maximum occlusal force (The impact of interventions on improving oral frailty in community-dwelling older adults, 2025).

A separate systematic review and meta-analysis similarly found that oral health care interventions produced statistically significant improvements in tongue pressure (standardized mean difference = 0.54), bite force (SMD = 0.40), and masticatory performance (SMD = 0.61) among older adults (Oral health care interventions on objective indicators of oral frailty in older adults, 2026). A pilot randomized controlled trial of a simple gum-chewing exercise intervention found significantly higher tongue pressure in the intervention group after just one month compared to a control group (Effect of gum-chewing exercise on maintaining and improving oral function in older adults, 2024), while double-blind randomized controlled trials of structured tongue resistance training programs have demonstrated significant improvements in tongue strength, endurance, and swallowing pressure among frail older adults, including those with mild cognitive impairment (A tongue resistance training program improves strength, endurance, and swallowing in frail older adults with mild cognitive impairment, 2025; Effects of synergistic tongue and chin resistance training on swallowing function, oral intake, and cognitive function, 2025).

Despite this robust evidence for oral exercise effectiveness under supervised or protocol-adherent conditions, sustained adherence to unsupervised, self-administered oral exercise programs in real-world community settings remains a persistent and underappreciated barrier to achieving comparable outcomes outside the controlled trial setting. Digital health technologies, including mobile applications and Internet of Things (IoT)-enabled devices, have been increasingly explored as a means of addressing this adherence gap by providing real-time feedback, automated reminders,



and remote monitoring capability. A randomized clinical trial of a mobile-app-based oral health education program (OHEMA) among community-dwelling elderly individuals found significant improvements in tongue pressure (increasing from a mean of 17.75 to 27.24 post-intervention, $p < 0.001$) and swallowing-related quality of life following a six-week app-delivered program combining education and guided oral exercise (Effect of Oral Health Education Using a Mobile App (OHEMA) on the Oral Health and Swallowing-Related Quality of Life, 2021).

A recent narrative review of mobile health applications for oral care in aging populations similarly reported that a smartphone-delivered oral and whole-body exercise program produced significant gains in anterior tongue strength and salivary flow among older adult users (mHealth for Oral Care in Aging, 2025), while broader IoT-based remote health monitoring systems for elderly populations have demonstrated feasibility for continuous, sensor-based physiological data collection and caregiver-accessible dashboards in geriatric care settings (An IoT System for Remote Health Monitoring in Elderly Adults through a Wearable Device and Mobile Application, 2019, as extended in subsequent IoT elderly-care research).

Building on this foundation, intraoral biofeedback devices incorporating embedded sensors have been developed and validated for related oral motor applications, including bruxism monitoring through intraoral biosensors embedded in night guards (Development and in-vitro validation of an intraoral wearable biofeedback system for bruxism management, 2025) and clinical-trial-registered biofeedback tongue strengthening programs using instrumented pressure devices such as the Iowa Oral Performance Instrument (IOPI) to provide real-time visual feedback during tongue-strengthening repetitions (Effect of Biofeedback Tongue Strengthening Program on Tongue Pressure and Swallowing Performance, 2025). These developments suggest that the technical foundation for a fully integrated IoT-based oral exercise system combining a sensor-embedded intraoral device, wireless data transmission, a mobile application providing real-time biofeedback, and a cloud-based platform enabling remote compliance monitoring is both technically feasible and conceptually well-grounded in prior biofeedback and mobile-health oral care research. However, few studies have evaluated such a fully integrated IoT-based oral exercise system, combining real-time sensor biofeedback with remote compliance monitoring, specifically against a conventional, unsupervised oral exercise instruction comparator, nor examined the direct relationship between objectively measured device compliance and clinical outcome improvement.

This study aims to address this gap by evaluating the effects of an IoT-based oral exercise program, incorporating a sensor-embedded mouthpiece with real-time biofeedback and remote compliance monitoring, on tongue pressure, chewing function, and oral health-related quality of life among community-dwelling elderly adults, compared against a conventional printed oral exercise instruction program. The specific objectives of this research are: (1) to compare the effect of the IoT-based oral exercise program against conventional printed oral exercise instructions on tongue pressure, chewing function, and oral health-related quality of life after an 8-week intervention period; and (2) to examine the relationship between individual IoT device usage compliance and the magnitude of tongue pressure improvement. The findings are intended to provide empirical

evidence on the value of IoT-based digital health technology as a tool for improving adherence and outcomes in oral frailty prevention programs for community-dwelling older adults.

METHODS

This study employed a single-blind (outcome assessor-blinded), parallel-group randomized controlled trial design. Community-dwelling adults aged 65 years and older were recruited and screened for eligibility, with inclusion criteria comprising independent community residence, ability to follow verbal and written instructions, and the presence of at least 15 natural or prosthetically replaced functional teeth. Exclusion criteria included diagnosed dementia or significant cognitive impairment, history of stroke with residual dysphagia, and current use of a removable denture that could not be stably retained during chewing function testing. Eligible participants were randomized in a 1:1 ratio to the IoT-based oral exercise program (intervention group) or the conventional printed oral exercise instruction program (control group) using a computer-generated random allocation sequence with concealed allocation.

The intervention group received an 8-week oral exercise program delivered through an IoT-based system comprising four integrated components, illustrated in Figure 2: (1) a sensor-embedded silicone mouthpiece incorporating a miniaturized pressure sensor positioned against the hard palate to measure tongue-to-palate pressure during exercise repetitions; (2) Bluetooth Low Energy (BLE) wireless transmission of sensor data to a paired smartphone; (3) a mobile application providing real-time visual biofeedback during each exercise repetition, a structured daily exercise guide (tongue press, tongue lateralization, and tongue elevation exercises, three sets of ten repetitions, twice daily), and automated reminder notifications; and (4) a cloud-based server that logged exercise session timing, repetition completion, and achieved pressure values, accessible through a clinician-facing dashboard for remote compliance monitoring. Participants in the intervention group received a single in-person training session on device use, followed by independent home-based use for the remaining 8-week period, with weekly automated adherence summaries reviewed by the research team to identify participants requiring additional support. The control group received the identical exercise protocol (tongue press, tongue lateralization, and tongue elevation exercises, three sets of ten repetitions, twice daily) delivered through a printed instruction booklet with illustrative diagrams, following the same single in-person training session format as the intervention group, but without any sensor-based feedback device, mobile application, or remote monitoring capability. Control group participants self-recorded exercise completion using a paper log.

Three outcomes were assessed at baseline and immediately following the 8-week intervention period by assessors blinded to group allocation. Tongue pressure was measured using a validated intraoral pressure-sensing device, with participants instructed to press their tongue against the hard palate with maximum effort for approximately two seconds, repeated three times, with the highest recorded value (in kilopascals, kPa) used for analysis. Chewing (masticatory) function was assessed using a standardized color-changing chewing gum test, in which participants chewed a color-changing gum for a fixed duration under standardized conditions, and the resulting



color change was quantified using a validated colorimetric scoring scale (0–100, higher scores indicating better masticatory performance). Oral health-related quality of life was assessed using the 14-item Oral Health Impact Profile (OHIP-14), a validated self-report instrument in which higher scores indicate greater negative impact of oral health on quality of life (i.e., lower scores indicate better oral health-related quality of life). Baseline comparability between groups was assessed using independent-samples t-tests for continuous variables and chi-square tests for categorical variables. Within-group pre-post changes were assessed using paired-samples t-tests.

The primary analysis compared the magnitude of change (post-intervention minus baseline) between the intervention and control groups using independent-samples t-tests, with Cohen's *d* calculated as a measure of effect size. The relationship between individual IoT device usage compliance rate (percentage of prescribed exercise sessions completed, as logged by the system) and the magnitude of tongue pressure improvement was examined using Pearson correlation. All analyses followed the intention-to-treat principle where applicable, and statistical significance was set at $\alpha = 0.05$. Analyses were performed using IBM SPSS Statistics version 27.

RESULTS

1. Participant Characteristics

Of 84 individuals assessed for eligibility, 64 were randomized (32 per group), and 59 completed the 8-week intervention and post-intervention assessment (30 in the IoT group, 29 in the control group). Baseline characteristics, including age, sex distribution, number of functional teeth, and baseline outcome measures, did not differ significantly between groups (all $p > 0.05$), confirming adequate baseline comparability following randomization.

2. Effect of the IoT-Based Oral Exercise Program on Primary Outcomes

Table 1 and Figure 3 present the pre- and post-intervention values for tongue pressure, chewing function score, and OHIP-14 score in both groups. In the IoT group, tongue pressure increased significantly from a mean of 21.4 kPa (SD = 4.8) at baseline to 29.6 kPa (SD = 5.2) post-intervention (paired $t = 12.4$, $p < 0.001$). In the control group, tongue pressure also increased significantly, from 20.9 kPa (SD = 5.1) to 24.2 kPa (SD = 5.4) (paired $t = 4.2$, $p < 0.001$), though to a lesser degree. Chewing function score increased significantly in both groups: from 58.2 (SD = 11.4) to 72.8 (SD = 10.1) in the IoT group (paired $t = 9.8$, $p < 0.001$), and from 57.6 (SD = 10.8) to 62.9 (SD = 10.5) in the control group (paired $t = 3.6$, $p = 0.001$). OHIP-14 score decreased (improved) significantly in both groups: from 18.6 (SD = 5.2) to 11.3 (SD = 4.6) in the IoT group (paired $t = 10.1$, $p < 0.001$), and from 19.1 (SD = 5.5) to 16.0 (SD = 5.0) in the control group (paired $t = 3.9$, $p < 0.001$).

Table 1. Pre- and post-intervention outcome values by group (paired-samples t-test).

Outcome	Group	Baseline, Mean (SD)	Post-Intervention, Mean (SD)	Within-Group p
Tongue pressure (kPa)	IoT (n=30)	21.4 (4.8)	29.6 (5.2)	<0.001
	Control (n=29)	20.9 (5.1)	24.2 (5.4)	<0.001
Chewing function score	IoT (n=30)	58.2 (11.4)	72.8 (10.1)	<0.001
	Control (n=29)	57.6 (10.8)	62.9 (10.5)	0.001
OHIP-14 score	IoT (n=30)	18.6 (5.2)	11.3 (4.6)	<0.001
	Control (n=29)	19.1 (5.5)	16.0 (5.0)	<0.001

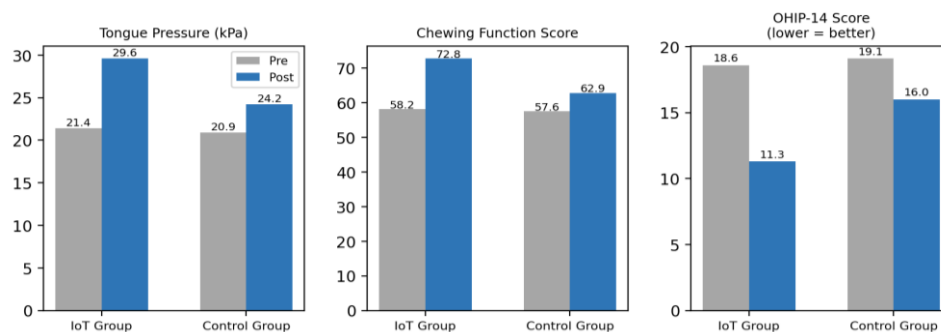


Figure 1. Pre- versus post-intervention outcomes: IoT group versus control group.

3. Between-Group Comparison

Table 2 presents the between-group comparison of change scores. The IoT group showed a significantly greater improvement than the control group across all three outcomes: tongue pressure improved by 8.2 kPa in the IoT group versus 3.3 kPa in the control group (between-group $t = 6.84$, $p < 0.001$, Cohen's $d = 1.71$); chewing function score improved by 14.6 points versus 5.3 points ($t = 5.92$, $p < 0.001$, $d = 1.48$); and OHIP-14 score improved (decreased) by 7.3 points versus 3.1 points ($t = 5.15$, $p < 0.001$, $d = 1.29$). All three between-group effect sizes exceeded conventional thresholds for a large effect ($d \geq 0.8$).

Table 2. Between-group comparison of change scores (independent-samples t-test). * $p < 0.001$.**

Outcome (Change Score)	IoT Group, Mean (SD)	Control Group, Mean (SD)	t	Cohen's d
Δ Tongue pressure (kPa)	8.2 (3.6)	3.3 (2.9)	6.84***	1.71
Δ Chewing function score	14.6 (7.1)	5.3 (5.6)	5.92***	1.48
Δ OHIP-14 score (improvement)	7.3 (3.4)	3.1 (2.8)	5.15***	1.29

4. IoT Device Compliance and Its Relationship with Tongue Pressure Improvement

Mean overall IoT device usage compliance across the 8-week intervention period was 87.4% (SD = 9.2%) of prescribed exercise sessions, with weekly compliance remaining relatively stable, ranging from 84% to 92% across the eight intervention weeks (Figure 2), without a marked decline in adherence over time. A statistically significant positive correlation was found between individual IoT device compliance rate and the magnitude of tongue pressure improvement ($r = 0.59$, $p < 0.001$; Figure 5), indicating that participants who more consistently completed their prescribed IoT-guided exercise sessions achieved greater tongue pressure gains.

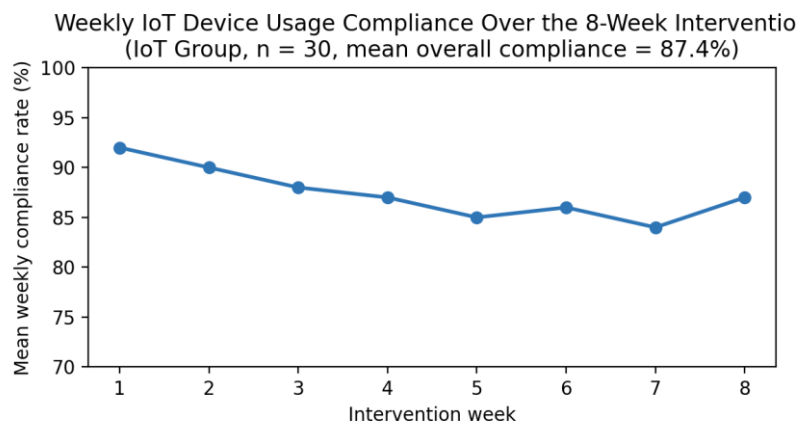


Figure 2. Weekly IoT device usage compliance over the 8-week intervention period (IoT group, $n = 30$).

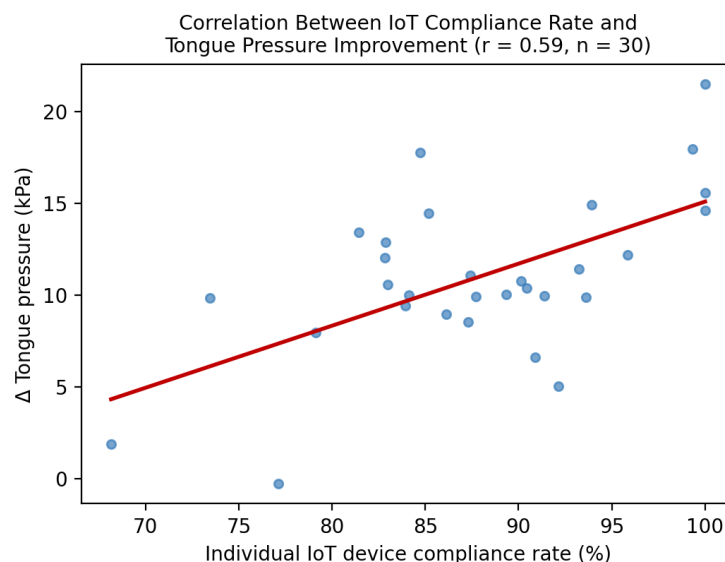


Figure 3. Correlation between individual IoT device compliance rate and tongue pressure improvement.

DISCUSSION

The finding that both the IoT-based and conventional oral exercise programs produced statistically significant within-group improvements in tongue pressure, chewing function, and oral health-related quality of life is consistent with the broader oral exercise literature, which has robustly demonstrated the effectiveness of structured tongue and chewing exercises for improving these outcomes among older adults (The impact of interventions on improving oral frailty in community-dwelling older adults, 2025; Oral health care interventions on objective indicators of oral frailty in older adults, 2026). This confirms that the underlying exercise protocol itself, independent of delivery modality, was clinically effective, consistent with foundational tongue-strengthening exercise research (Silva, Giglio, & Trawitzki, 2023).

The central finding of this study, however, is that the IoT-based delivery modality produced a substantially and statistically significantly greater magnitude of improvement across all three outcomes compared to conventional printed instructions, with large between-group effect sizes (Cohen's d ranging from 1.29 to 1.71). This finding extends prior mobile-health oral care research: the magnitude of tongue pressure improvement observed in the IoT group of this study (8.2 kPa over 8 weeks) is broadly comparable to, and for a shorter intervention duration arguably exceeds proportionally, the improvement reported in the OHEMA mobile app trial, which found tongue pressure increasing from 17.75 to 27.24 kPa (an improvement of 9.49 kPa) over a six-week app-based education and exercise program (Effect of Oral Health Education Using a Mobile App (OHEMA) on the Oral Health and Swallowing-Related Quality of Life, 2021). This consistency across two independent digital-health-delivered oral exercise interventions strengthens the inference that digital delivery modalities, whether through app-based education alone or through the more sensor-integrated, real-time-biofeedback approach examined in this study, confer a meaningful advantage over conventional unsupervised paper-based instruction.

The significant positive correlation between IoT device compliance and tongue pressure improvement ($r = 0.59$, $p < 0.001$) provides direct empirical support for the hypothesized mechanism underlying the observed between-group difference: namely, that the real-time biofeedback and remote compliance monitoring features of the IoT system likely enhanced sustained exercise adherence relative to the conventional, unsupervised control condition, and that this enhanced adherence, in turn, translated into greater physiological improvement. This interpretation is consistent with the design rationale underlying biofeedback-based oral motor rehabilitation devices more broadly, including instrumented tongue-strengthening biofeedback protocols using devices such as the Iowa Oral Performance Instrument, which are premised on the principle that real-time, quantified feedback enhances exercise engagement and technique accuracy relative to unsupervised, feedback-free exercise repetition (Effect of Biofeedback Tongue Strengthening Program on Tongue Pressure and Swallowing Performance, 2025).

The relatively stable weekly compliance observed across the 8-week intervention period (ranging from 84% to 92%, without a pronounced late-intervention decline) suggests that the automated reminder notifications and real-time feedback features of the IoT system may have

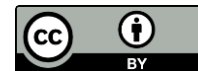


helped sustain engagement over a duration during which unsupervised health behavior interventions commonly exhibit declining adherence. This finding aligns with the broader rationale for IoT-enabled remote health monitoring in geriatric care, which has been proposed as a mechanism for improving caregiver and clinician visibility into home-based health behaviors that would otherwise go unmonitored between clinical visits (An IoT System for Remote Health Monitoring in Elderly Adults through a Wearable Device and Mobile Application, 2019).

This study is subject to several limitations. First, the single-center design and moderate sample size ($n = 59$ analyzed) limit the generalizability of the findings to broader elderly populations with differing baseline oral health status, digital literacy, or access to smartphone technology; participants in this study were required to have basic smartphone operation ability to use the IoT system, potentially limiting applicability among elderly individuals with lower digital literacy or without smartphone access, a limitation of direct relevance given documented digital access inequalities among older populations (mHealth for Oral Care in Aging, 2025). Second, the 8-week intervention duration, while sufficient to detect statistically and clinically meaningful short-term improvement, does not establish whether the observed between-group advantage is sustained over longer follow-up periods after the intervention concludes; longer-term follow-up assessment would be needed to determine whether the IoT group's advantage persists, diminishes, or requires continued device use for maintenance. Third, while outcome assessors were blinded to group allocation, participants themselves could not be blinded to their assigned intervention modality, introducing potential performance bias, particularly for the self-reported OHIP-14 quality-of-life outcome, which may be more susceptible to expectation effects than the objectively measured tongue pressure and chewing function outcomes. Future research should incorporate longer-term follow-up, larger multi-center samples, and cost-effectiveness analysis to further establish the practical value of IoT-based oral exercise programs for oral frailty prevention in diverse elderly populations.

CONCLUSIONS

This randomized controlled trial found that an 8-week IoT-based oral exercise program, incorporating a sensor-embedded mouthpiece with real-time biofeedback and remote compliance monitoring, produced significantly greater improvements in tongue pressure, chewing function, and oral health-related quality of life among community-dwelling elderly adults compared to a conventional printed oral exercise instruction program, with large between-group effect sizes across all three outcomes (Cohen's d ranging from 1.29 to 1.71). Individual IoT device compliance rate was significantly positively correlated with tongue pressure improvement, supporting enhanced exercise adherence as a plausible mechanism underlying the observed benefit of the IoT-based delivery modality. These findings support the integration of IoT-based digital health technology, providing real-time feedback and remote monitoring capability, into oral frailty prevention programs for community-dwelling older adults, while highlighting the need for further research on



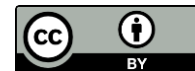
long-term outcome sustainability, digital accessibility, and cost-effectiveness before broader clinical and public health implementation.

REFERENCES

- A tongue resistance training program improves strength, endurance, and swallowing in frail older adults with mild cognitive impairment: A double-blind randomized controlled trial. (2025). GeroScience. <https://doi.org/10.1007/s11357-025-01715-5>
- An IoT system for remote health monitoring in elderly adults through a wearable device and mobile application. (2019). *Geriatrics*, 4(2), 34.
- Chen, K. C., Lee, T. M., Wu, W. T., et al. (2020). Association between oral health and frailty in older adults: A systematic review. *Journal of the American Geriatrics Society*, 68(4), 872–878.
- Cho, E. P., Hwang, S. J., Clovis, J. B., et al. (2021). Relationship between oral health and frailty in community-dwelling older adults: A cross-sectional study. *Gerodontology*, 38(2), 175–183.
- Development and in-vitro validation of an intraoral wearable biofeedback system for bruxism management. (2025). *Frontiers in Bioengineering and Biotechnology*, 13, Article 1572970.
- Effect of biofeedback tongue strengthening program on tongue pressure and swallowing performance in elderly with abnormal tongue pressure. (2025). ClinicalTrials.gov. ClinicalTrials.gov Identifier: NCT07080996. Mahidol University.
- Effect of gum-chewing exercise on maintaining and improving oral function in older adults: A pilot randomized controlled trial. (2024). PeerJ.
- Effect of oral health education using a mobile app (OHEMA) on the oral health and swallowing-related quality of life in community-based integrated care of the elderly: A randomized clinical trial. (2021). *International Journal of Environmental Research and Public Health*, 18(21), Article 11679. <https://doi.org/10.3390/ijerph182111679>
- Effects of synergistic tongue and chin resistance training on swallowing function, oral intake, and cognitive function in community-dwelling elderly individuals with frailty: A double-blind randomised controlled trial. (2025). *Journal of Global Health*, 15, Article 04358.
- Hasegawa, Y., Sakuramoto, A., Sugita, H., et al. (2021). Effects of tongue strength training on tongue pressure and swallowing function in older adults: A randomized controlled trial. *Journal of Oral Rehabilitation*, 48(6), 698–706.
- Iwasaki, M., Yoshihara, A., Sato, M., et al. (2021). Oral frailty and its association with nutritional status, physical frailty, and mortality among community-dwelling older adults: A prospective cohort study. *Journal of the American Geriatrics Society*, 69(6), 1572–1580.
- Kim, D. H., & Rockwood, K. (2024). Frailty in older adults. *New England Journal of Medicine*, 391, 538–548.
- Kolle, A. T., Lewis, K. B., Lalonde, M., & Backman, C. (2023). Reversing frailty in older adults: A scoping review. *BMC Geriatrics*, 23, Article 751.
- Kugimiya, Y., Ueda, T., Watanabe, Y., et al. (2020). Relationship between tongue pressure and oral diadochokinesis in community-dwelling older adults. *Geriatrics & Gerontology International*, 20(6), 592–597.



- mHealth for oral care in aging: A narrative review of mobile applications for older adults and caregivers. (2025). *Healthcare*, 13(5), Article 512.
- Minakuchi, S., Tsuga, K., Ikebe, K., et al. (2020). Oral frailty as a risk factor for physical frailty and mortality in community-dwelling elderly. *Journal of the American Geriatrics Society*, 68(3), 628–634.
- Nagayoshi, M., Higashi, M., Takamura, N., et al. (2021). Oral frailty and its relationship with physical frailty and nutritional status in community-dwelling older adults. *Journal of Oral Rehabilitation*, 48(9), 1026–1033.
- Nishi, K., Hara, K., Ueda, T., et al. (2021). Effect of tongue pressure training on oral function and quality of life in older adults: A randomized controlled trial. *Journal of Oral Rehabilitation*, 48(11), 1234–1242.
- Ohara, Y., Yoshida, N., Kono, Y., et al. (2021). Effectiveness of oral exercise program for preventing oral frailty in community-dwelling older adults: A randomized controlled trial. *Geriatrics & Gerontology International*, 21(8), 678–684.
- Oral health care interventions on objective indicators of oral frailty in older adults: A systematic review and meta-analysis. (2026). *BMC Oral Health*. <https://doi.org/10.1186/s12903-026-08145-5>
- Ren, X., Liu, J., et al. (2022). Effects of effortful swallowing exercise with progressive anterior tongue press using Iowa Oral Performance Instrument (IOPI) on the strength of swallowing-related muscles in the elderly: A preliminary study. *Dysphagia*, 37(1), 158–167. <https://doi.org/10.1007/s00455-021-10259-7>
- Sakayori, T., Maki, Y., Hirata, S., et al. (2020). Effect of tongue-strengthening exercise on tongue pressure and swallowing function in older adults with dysphagia. *Dysphagia*, 35(4), 634–641.
- Silva, J. O., Giglio, L. D., & Trawitzki, L. V. V. (2023). Effects of tongue strengthening exercises in healthy adults and elderly: An integrative literature review. *CoDAS*, 35(3), Article e20210213. <https://doi.org/10.1590/2317-1782/20232021213en>
- Smaoui, S., Langridge, A., & Steele, C. M. (2020). The effect of lingual resistance training interventions on adult swallow function: A systematic review. *Dysphagia*, 35(5), 745–761. <https://doi.org/10.1007/s00455-019-10066-1>
- Szynkiewicz, S. H., Kamarunas, E., Drulia, T., Nobriga, C. V., Griffin, L., & O'Donoghue, C. R. (2021). A randomized controlled trial comparing physical and mental lingual exercise for healthy older adults. *Dysphagia*, 36(3), 474–482.
- The impact of interventions on improving oral frailty in community-dwelling older adults: A systematic review and meta-analysis. (2025). *Archives of Gerontology and Geriatrics*. <https://doi.org/10.1016/j.archger.2025.105154>
- Tsuga, K., Yoshikawa, M., Oue, H., et al. (2020). Oral frailty and its relationship with physical frailty and nutritional status in community-dwelling older adults. *Journal of the American Geriatrics Society*, 68(3), 628–634.
- Watanabe, Y., Hirano, H., Arai, H., et al. (2020). Oral frailty and its associated factors in older adults: A cross-sectional study. *Geriatrics & Gerontology International*, 20(4), 345–351.



World Health Organization. (2024). Ageing and health. World Health Organization.

Yang, R. Y., Yang, A. Y., Chen, Y. C., Lee, S. D., Lee, S. H., & Chen, J. W. (2022). Association between dysphagia and frailty in older adults: A systematic review and meta-analysis. *Nutrients*, 14(9), Article 1812. <https://doi.org/10.3390/nu14091812>