Effectiveness of Animated Media in Tongue Strengthening Exercise Learning

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Abstract

Tongue strengthening exercise (TSE) is a well-established form for improving tongue strength and endurance. Considering the multifaceted nature of these exercises, instructional media like sequential pictures and animated media offer accessible alternatives for TSE.

This prospective cohort study aimed to compare the learning effectiveness of TSE using these 2 mediums. Sixty non-dental individuals were divided into 3 age groups ($\leq$15, 25-35, and $\geq$55 years) and randomly assigned to either the sequential pictures group (n=30) or the animated media group (n=30). Participants were instructed in three tongue exercises (tongue paint, tongue click, and tongue corner) via the Line application and recorded their performances shortly after the learning session. Blinded evaluators rated and analyzed the exercise scores. The findings indicated that, overall, animated media led to higher scores in all practices. Notably, participants aged $\geq$55 years showed a significant decreased in total TSE scores in the static picture group compared to the animated media group (P=0.02) However, no significant difference in total TSE scores between males and females.

The results of this study demonstrate that animated media is an accessible and effective method for motor skill learning of TSE, particularly beneficial for older participants who faced challenges with static pictures.

Clinical article (J Int Dent Med Res 2025; 18(1): 245-252)

Keywords: Tongue strengthening exercise, sequential pictures, Animation, Learning, Human movement.

Received date: 30 September 2024 **Accept date:** 01 February 2025

Introduction

The tongue plays a pivotal role in several functions, including mastication, swallowing, speech, and sleep. In the context of food intake, the tongue collaborates with the jaw, aiding in moving food for chewing by the back teeth and generating pressure to guide and propel the bolus through the oral cavity and pharynx, also contributing to airway safeguarding.[1] Moreover, the tongue and hard palate are essential in sound production during continuous speech, with tongue shape variations being tied to distinct phoneme categories. For instance, in producing the sound /s/, the sides of the tongue touch the lateral palate and inner teeth surface, forming a tongue groove along the midline of the vocal tract to direct airflow towards the incisors.[2] Conversely, for the sound /r/, the sides of the tongue are elevated while the midline is lowered.[3] Another significant role of the tongue is its function as a key pharyngeal dilator muscle. Of note, the genioglossus muscle, a major component of the tongue, is believed to have a crucial role in maintaining upper airway patency during sleep.[4]

Numerous studies indicate a potential correlation between oral dysfunctions and restricted tongue function or weakness.[5,6] This connection has been observed in various contexts, including ankyloglossia, post-oral cancer treatment, elderly individuals, and those with dysphagia.[7-10] In response to these limitations, compensatory dysfunctional lingual motor patterns tend to emerge. These patterns involve prioritizing certain muscles over others, ultimately hampering the development and proper functioning of the stomatognathic system. Tongue strengthening exercise (TSE) has emerged as a valuable approach to address such

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issues. TSE has shown efficacy in improving aspects like tongue resting posture, muscle coordination, wound healing, and functional recovery.[7] Furthermore, TSE contributes to enhancing tongue strength and response rates,[11] which is particularly beneficial for individuals dealing with reduced muscle function due to conditions like predysphagia and dysphagia.[8,12] Ultimately, TSE has been found to positively impact overall quality of life.[13]

Effective instruction for proper tongue muscle training is essential to ensure patients acquire proficient procedural skills. As demonstrated in skill performance studies such as basic life support (BLS), Pederson et al.[14] found that self-directed learning was comparable to facilitator-led learning using the same kit and duration. The self-learning group maintained their skill level and even outperformed the facilitator-led group after three months. Motor skill learning employs various methods, including oral explanations, visual aids like static or sequential pictures, and videos. Cognitive effort is believed to decrease when learners create mental pictorial representations through animated narration instead of static illustrations.[15] While some studies highlight animation's engagement of the mirror neuron system, leading to more realistic model visualization. H'mida et al.[16] found that the continuous video generated better learning performances than simultaneous-permanent pictures, sequential-transient pictures, and sequential-permanent pictures. Despite these insights, there is currently no definitive evidence supporting the most effective approach for acquiring and practicing procedural skills in TSE. This study's objective is to compare the learning effectiveness of two methods: static pictures and animated media. The hypothesis underlying this study is that employing animated media as a learning tool for TSE enhances patients' comprehension and the precision of their procedural skills more effectively than static images.

Materials and methods

The research was conducted with the approval of the ethics committee at the Faculty of Dentistry, Chulalongkorn University, Thailand. Between March and October 2021, a total of 60 subjects participated in this prospective cohort study, selected based on specific criteria. This retrospective study was approved by The Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2021-0xx). Informed consent was obtained from all participating adult subjects, and parents or legal guardians of minors or incapacitated adults.

Inclusion criteria:
- Individuals who are Thai or understand and are fluent in Thai.
- Age between 5 and 65 years old, with each age group representing children, young adults, and the elderly.
- Possession of electronic devices capable of supporting the Line application and recording videos. In cases where children or the elderly do not possess a device, they may use those of their relatives or caregivers. However, these individuals cannot provide advice on any step of the TSE.

Exclusion criteria:
- Individuals working as dentists or in dental-related careers.
- Presence of ankyloglossia.
- Pre-existing conditions such as Parkinson's disease, Myasthenia gravis, Demyelinating diseases, Motor neuron diseases, Muscular or connective tissue disorders, or any other conditions affecting tongue mobility.
- Orofacial congenital deformities or orofacial syndromes.
- History of prior myofunctional therapy.
- Diagnosis of mental retardation, depression, schizophrenia, attention deficit disorder, or hyperactivity.

The participants were randomly divided into two equal groups: the static pictures group (control group) and the animated group (experimental group). Subsequently, the study instructions and three TSEs were sequentially delivered through the Line application on cellphones, utilizing either static images or animations. The animated media utilized in this study contained an equivalent amount of information as the static picture group. The sole distinction was that the information in the animated media was presented in an automatic sequential manner. Participants learned and recorded themselves performing the first TSE, sending the recording back to the first examiner within a 10-minute timeframe. Afterward, the second exercise instruction was dispatched, and this process was repeated until participants

completed all three exercises. All TSE video clips were then forwarded to the second examiner, who remained blinded to the group assignments. The examiner assessed and assigned a score ranging from 0 to 4 for each exercise.

A single examiner was responsible for assigning all the rating scores. To ensure the reliability of the TSE rating scale, the same 20 participants were selected randomly, and their TSEs were rated again after an interval of 14 days before the main experiment.

The participants were instructed to perform the following TSEs:

1. Tongue Paint:

Touch the tip of your tongue to the front part of the palate and flatten your tongue against this area, then pull your tongue backward as much as possible, as if you are "painting" with your tongue and hold this position for 5 seconds. Repeat this movement 5 times. (Refer to Figure 1 for visual representation).
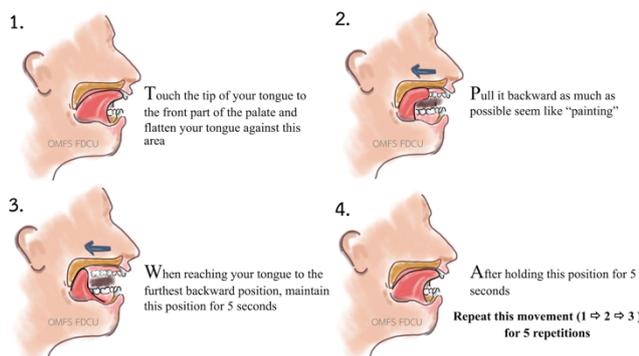

Figure 1. Illustration of tongue paint.

In the scoring system used:

- A score of 4 (excellent) indicated that participants performed the posture and movement accurately.
- A score of 3 (good) indicated that performed the main movements accurately and consistently. This involves placing the tongue in the correct position and gently retracting it backward but incomplete holding or repetitions the posture for less than 5 seconds or 5 times, respectively.
- A score of 2 (fair) indicated that performed most of the main movements accurately but not entirely. This involves placing the tongue in the correct position before initiating the movement, but backward movement was not slow and controlled or not consistent contact between the tongue and the palate throughout

the exercise or cannot work on extending the tongue movement to the most posterior of the palate or cannot maintaining a clear and regular tongue movement.

- A score of 1 (poor) indicated that performed consistently assuming the main movements but not executing it correctly. This involves placing the tongue in the correct position but no backward movement.
- A score of 0 (fail) indicates that participants were unable to perform the movement.

2. Tongue Corner:

Open your mouth and extend the tip of your tongue forward to the left corner of the lips, then move the tip of your tongue to the right corners of the lips, this left and right movement counts as 1 repetition. Repeat this movement 5 repetitions. (Refer to Figure 2 for visual representation).
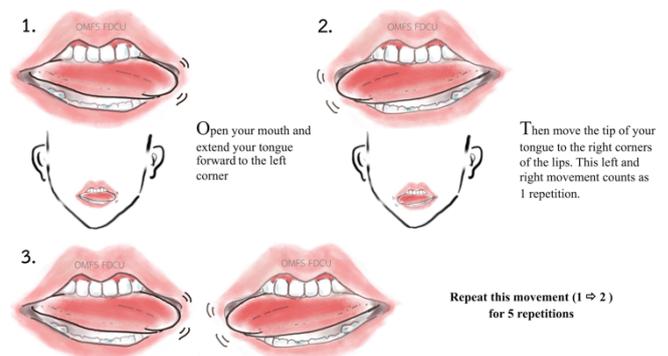

Figure 2. Illustration of tongue corner

In the scoring system used:

- A score of 4 (excellent) indicated that participants performed the posture and movement accurately.
- A score of 3 (good) indicated that performed the main movements accurately and consistently. This involves placing the tongue in the correct position and moving it to touch the left and right corners of the mouth, but not completing the movement 5 repetitions.
- A score of 2 (fair) indicated that performed most of the main movements accurately but not entirely. This involves placing the tongue in the correct position and moving the tongue touching the left and right corners of the mouth. However, the movement direction might not be clear, continuous, or even.
- A score of 1 (poor) indicated that performed consistently assuming the main movements but not executing it correctly. This involves the

tongue do not touching the corner of the mouth.

- A score of 0 (fail) indicates that participants were unable to perform the movement.

3. Tongue Click:

Elevate the tip of your tongue to touch the front part of the palate and flatten your tongue against this area as if you are making a sucking motion, then make a 'click' sound by bringing the tongue down. Repeat this movement 5 repetitions. (Refer to Figure 3 for visual representation).
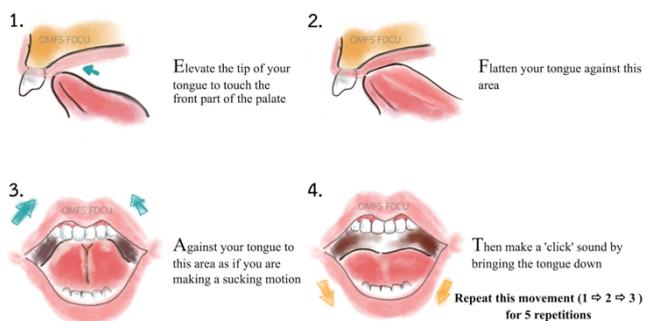

Figure 3. Illustration of tongue click.

In the scoring system used:

- A score of 4 (excellent) indicated that participants performed the posture and movement accurately.
- A score of 3 (good) indicated that performed the main movements accurately and consistently. This involves placing the tongue in the correct position and against the front part of the palate before clicking it, but not completing the movement 5 repetitions.
- A score of 2 (fair) indicated that performed most of the main movements accurately but not entirely. This involves placing the tongue in the correct position, being able to click the tongue but do not flatten the tongue before clicking the tongue.
- A score of 1 (poor) indicated that performed consistently assuming the main movements but not executing it correctly. This involves no clicking sound, or the sound is not caused by clicking the tongue.
- A score of 0 (fail) indicates that participants were unable to perform the movement.

Statistical Analysis

Intra-rater reliability was assessed using intra-class correlation coefficients. The Kolmogorov-Smirnov test was employed to assess the normality of the data distribution. Continuous data were presented as mean ± standard deviation. The TSE scores and the cumulative scores of the three exercises were compared between the static pictures group and the animated group using the Mann-Whitney U test. Pearson correlation analysis was conducted to examine the relationships among the scores of the three TSEs and the total TSE scores. Additionally, potential factors associated with total TSE scores exceeding 75% were examined through binary logistic regression using the enter method. These factors encompassed patient age categories (≤15, 25-35, and ≥55 years) and gender (male/female). Odds ratio (OR) estimates along with corresponding 95% confidence intervals (95% CI) were obtained from the intercept of each factor. All statistical analyses were conducted using the SPSS 21.0 software package (SPSS, Inc., Chicago, IL, USA). A significance level of $P < 0.05$ was considered statistically significant.

Results

A total of 60 subjects successfully completed the study. The baseline demographic characteristics are summarized in Table 1, with no significant differences observed between the static and animated groups. The intra-observer agreement for the tongue paint exercise was 0.977, for the tongue click exercise was 0.998, and for the tongue corner exercise was 0.978. The average intra-class correlation coefficient across these exercises was 0.984, demonstrating excellent intra-observer agreement in rating the tongue exercises.

	Static group	Animated group	P-value
Sex (Male/ Female; n)	11/19	10/20	0.79[a]
Age (Mean ± SD; years)	31.73 ± 20.265	31.43 ± 19.715	0.99[b]

Table 1. Subjects' characteristic data (sex and age) of static and animated groups.

[a] P-value by Chi-square test, [b] P-value by Mann-Whitney U Test, significant at P-value < 0.05.

Scores for tongue paint and tongue click exercises displayed significant correlations in both groups, whether using static or animated instructions. Notably, all individual tongue exercise scores demonstrated a significant

correlation with the total tongue exercise scores in both the static and animated groups (Table 2).

Variable		Tongue Paint	Tongue Click	Tongue Corner	Total TSEs
Tongue Paint	Coefficient	-	0.22	0.429	0.805
	P-value	-	0.092	0.001**	<0.001**
Tongue Click	Coefficient	-	-	0.302	0.496
	P-value	-	-	0.019*	<0.001**
Tongue Corner	Coefficient	-	-	-	0.831
	P-value	-	-	-	<0.001**

Table 2. Spearman's correlation among tongue exercise's scores and total TSE scores.
TSE=tongue strengthening exercise, *significant at P-value < 0.05, ** significant at P-value < 0.01.

		Total TSE scores (Mean ± SD)		P-value
		Static group	**Animated group**	
Age groups	≤15 years	8.2±3.8	9±2.11	0.76[b]
	25-35 years	10.3±1.57	10.7±1.7	0.48[b]
	≥55 years	6.5±1.6	8.6±2.46	0.02[b]*
	P-value	0.01[a]*	0.08	
Gender	Male	7.27±3.23	9.8±1.99	0.06
	Female	8.95±2.61	9.25±2.38	0.8
	P-value	0.13	0.58	

Table 3. Comparison of total TSE scores (tongue paint, tongue corner, and tongue click) between static and animated groups (categorized by age groups and gender).
SD=standard deviation, [a] P-value by Kruskal-Wallis Test, [b] P-value by Mann-Whitney U Test,   *significant at P-value < 0.05.

The accuracy of the total tongue strength exercises (tongue paint, tongue corner, and tongue click), instructed using both static and animated media, has been categorized by age and gender. The results are presented in Table 3 for age-based categorization and gender-based categorization. The specific details for each exercise can be found in Figure 4a-4c (for age-based categorization) and Figure 5a-5c (for gender-based categorization).

Independent Variables	Category	P-value	Odd ratio	95% IC	
				Lower	**Upper**
Static group					
Age groups	≤15 years				
	25-35 years	0.13	6.99	0.548	89.015
	≥55 years	0.04*	0.06	0.004	0.872
Gender	Female				
	Male	0.04*	0.75	0.006	0.871
Animated group					
Age groups	≤15 years				
	25-35 years	0.15	6.05	0.534	68.67
	≥55 years	0.62	0.64	0.107	3.828
Gender	Female				
	Male	0.66	1.48	0.255	8.644

Table 4. The binary logistic regression analysis of factors related to total TSE scores >75%.
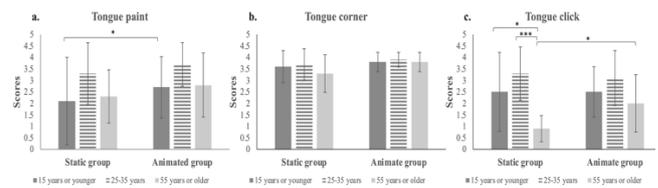*significant at P-value < 0.05.

Figure 4. The accuracy of the total tongue strength exercises (a. tongue paint, b. tongue corner, and c. tongue click), instructed using both static and animated media (for age-based categorization).
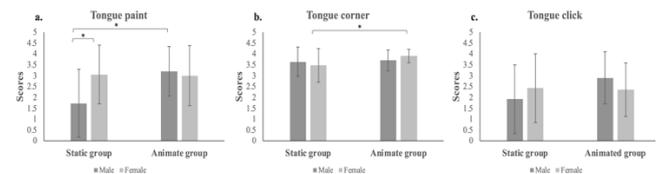

Figure 5. The accuracy of the total tongue strength exercises (a. tongue paint, b. tongue corner, and c. tongue click), instructed using both static and animated media (for gender-based categorization)**.**

The binary logistic regression analysis unveiled those individuals aged ≥55 years and male participants had a statistically significant correlation with achieving total TSE scores surpassing 75% in the static group. However, in the animated group, no significant distinctions were observed across all variables (refer to Table 4). The odds ratios highlighted that individuals aged ≥55 years and males were respectively 0.06 and 0.75 times as likely to attain a total TSE score of 75% compared to their counterparts aged ≤15 years and females, respectively (Table 5).

Discussion

Tongue strengthening exercise, or TSE, has demonstrated its efficacy and widespread use in enhancing tongue function. This technique's convenience lies in its portability and absence of specialized instruments, demanding minimal physical exertion. In this pioneering experimental study, we sought to compare the efficacy of two different learning methods for TSE: static pictures and animated media.

Numerous tongue exercises have been introduced, yet their comparative effectiveness remains unexplored. This study developed self-tongue strengthening exercises, building upon previous research in this area. Tongue paint and

tongue click exercises drew inspiration from Yano et al.[17] and Kim et al.[18], respectively, both simulating tongue muscle function during food bolus formation. Meanwhile, the tongue corner and tongue click exercises were designed to replicate tongue muscle movement during speech, eating, and swallowing.[19] Encouragingly, our study's findings were consistent with these earlier investigations. Positive correlations were observed between TSE scores for tongue paint and tongue click, as well as for tongue corner and tongue click exercises. Furthermore, all tongue exercise scores exhibited a positive correlation with total TSE scores, implying that these various tongue movements are interrelated and collaborate for effective functionality.

Simultaneous static pictures offer distinct advantages for learning continuous pattern tasks. They facilitate visual comparisons between different phases, enabling individuals to focus on each step while also being suitable for printing purposes.[16] On the other hand, animated media emerges as an appealing method due to its online accessibility. Animated media creates a personalized learning environment that accommodates flexible scheduling and location preferences. This medium also automatically engages the mirror neuron system, enhancing the processing of transient information. While patients can observe the actual movements, this approach may necessitate specific devices for optimal use.[20]

Previous research has suggested that age and gender can significantly influence intellectual styles and abilities.[21] In our study, we observed that individuals aged 25-35 years achieved the highest total TSE scores in both the static picture and animated media groups, although this difference was not statistically significant. Notably, only the total TSE scores of participants aged ≥55 years showed a significant decrease in the static picture group compared to those using animated media. Interestingly, the significant differences in total TSE scores among age groups were only evident in the static picture group, with no such differences found in the animated media group.

The tongue exercises were categorized based on their motion representation: tongue paint for antero-posterior movement, tongue corner for lateral movement, and tongue click for vertical movement. Upon closer examination of the specific exercises, intriguing patterns came to light. Within the static picture group, individuals aged ≥55 years achieved significantly lower scores in the "tongue click" exercise compared to those aged ≤15 years and aged 25-35 years. This age group also had the lowest overall scores. However, in the animated media group, individuals aged ≥55 years who performed the "tongue click" exercise achieved significantly higher scores compared to their counterparts aged ≥55 years in the static picture group performing the same exercise.

The complexity of TSE, involving the coordination of various oral structures, might pose challenges for elderly participants to understand and accurately replicate the movements. Aging has been linked to a decline in the ability to simultaneously process and respond to visual stimuli, known as visuospatial working memory (vWM).[22] This decline is attributed to diminished perceptual ability, decreased attention selection efficiency, and reduced short-term storage capacity. Tagliabue et al.[23] have proposed that repetition-based learning can effectively enhance vWM in aging individuals. This suggests that our animated media, which features repeated movements played 5 repetitions, could be more effective in aiding the elderly's learning compared to static pictures, particularly in exercises involving vertical tongue movement.

When examining gender as a factor, we found no significant difference in total TSE scores between males and females in both the static pictures and animated media groups. Notably, the scores were higher in the animated media group for both genders. When we delved into the specific exercises, some interesting patterns emerged. In the static picture group, males scored significantly lower than females in the "tongue paint" exercise and had the lowest scores overall. However, in the animated media group, males performing the "tongue paint" exercise scored significantly higher than males in the static picture group for the same exercise. Furthermore, females in the animated media group performing the "tongue corner" exercise also achieved significantly higher scores than females in the static picture group performing the same exercise.

A binary logistic model was employed to assess the research hypothesis concerning variations in total TSE scores between the static picture and animated media learning methods in

relation to age and gender. The outcomes indicated that individuals aged ≥55 years and males were less likely to achieve total TSE scores >75% compared to their younger and female counterparts in the static picture group. However, the odds of age and gender did not significantly influence outcomes in the animated media group. This suggests that animated media might mitigate factors that could potentially impact the TSE learning process.

This trend aligns with findings from a systematic review conducted by Shariff et al.,[20] which concluded that the combination of text and animation is effective in enhancing the acquisition of both technical and cognitive skills within procedural-based educational platforms. This approach is also well-received as an educational resource. The results suggest that animated media has the potential to offer benefits in terms of learning and executing tongue exercises, particularly for different age and gender groups.

The current study faced several limitations. The quality of participants' cellphones varied which in turn affected the examiner's ability to accurately score the exercises. Moreover, the animated media employed in this research had a relatively low frame rate, potentially not capturing the full movement of the tongue. Future studies could consider comparing static pictures to animated videos with smoother motion or incorporating sound effects to enhance the clarity of tongue exercises, such as including the clicking sound during the tongue click exercise. Additionally, to establish more robust findings, statistical analyses would benefit from a larger sample size to better identify significant relationships.

Conclusions

The effectiveness and success of TSE are influenced by the teaching materials employed. Notably, animated media appeared to be a more efficacious learning approach for TSE learning compared to static pictures, especially when considering the coordination of oral structures in vertical movement, can be challenging for elderly participants. The effectiveness of animated media in enhancing performance was more pronounced in specific exercises for both males & females.

Acknowledgement

Declaration of Interest

There is no financial or other consideration that could lead to a conflict of interest in this paper.

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