

# Effects of masticatory exercise on cognitive function in community-dwelling older adults

Tae-Hoon Kim

*Department of Occupational Therapy, Division of Health Sciences, Dongseo University, 47 Jurye-ro, Sasang-gu, Busan 47011, Korea*

*Tel.: +82 51 320 2718; Fax: +82 51 320 2721; E-mail: context@dongseo.ac.kr*

## **Abstract.**

**BACKGROUND:** Mastication improves cognitive function by activating cerebral cortical activity, and it is important to demonstrate the cognitive effects of masticatory training using a variety of different interventions.

**OBJECTIVE:** This study aimed to evaluate the effects of masticatory exercise on cognitive function in healthy older adults living in the community.

**METHODS:** For six weeks, twelve participants performed a masticatory exercise using a NOSICK exerciser device, and thirteen subjects performed daily life without masticatory exercises. Trail Making Test, Digit Span Test, and Stroop test were used to measure the cognitive function.

**RESULTS:** The participants in the experimental group showed significant improvements in TMT-A/B ( $p = 0.001$  and  $0.004$ ), DST-forward ( $p = 0.001$ ), and ST-word ( $p = 0.001$ ). The effect sizes after the intervention were calculated as (1.2 and 0.8) for TMT-A/B, (0.8 and 0.2) for Digit Span Test forward/backward, and (0.6 and 0.2) for Stroop test color/word.

**CONCLUSIONS:** We suggest that the masticatory exercises improve cognitive function in healthy older adults. Therefore, masticatory exercises can be used as a therapeutic exercise during cognitive rehabilitation.

Keywords: Cognitive function, masticatory exercise, older adults

## **1. Introduction**

Cognitive decline and a sharp increase in the prevalence of dementia in the aging population have prompted extensive research to identify modifiable factors. Cognitive decline is due to cerebral neurophysiological changes such as cortical atrophy and loss of neurons, cell groups, and synaptic loss [1]. These changes result in executive dysfunction that impacts their ability to engage in activities of daily living (ADL), work and recreational activities [2]. Strategies to prevent cognitive decline and tests for cognitive impairment have been considered important, and physical activities and cognitive improvement programs to trigger brain activation are mainly preventative approaches [3].

Mastication improves cognitive function by activating cerebral cortical activity and increasing cortical blood flow [4]. Kubo et al. [5] found that cerebral hemoglobin levels increase in the hippocampus and frontal cortex of the central nervous system during mastication, and that mastication increases neuronal activities for learning and memory. Thus, mastication can affect the brain's nervous system and help prevent brain deterioration. Some animal studies have shown that decreased mastication affects the function and morphology of hippocampal neurons, which are essential for learning [6,7]; this is supported by cross-sectional epidemiological studies in humans. Older adults with low cognitive function were more likely to have low chewing ability and poor oral health [8]. Not all human studies in this field have shown

a beneficial relationship between mastication and cognitive function, but some studies have supported the effectiveness of masticatory exercises. Tucha et al. [9] showed that chewing gum had a positive effect on cognitive functioning, especially memory. Hirano et al. [10] also found that gum chewing improved both spatial working memory and episodic memory. Other previous studies have suggested that chewing gum enhances the alerting effect and sustained attention performance [11–13].

Previous related studies have been conducted on the effects of masticating gum training on cognitive function, and it is important to demonstrate the cognitive effects of masticatory training using a variety of different interventions. It is important to use safe masticatory exercise equipment because of the possibility of unintentional swallowing and the risk of airway aspiration when chewing objects such as gum. In addition, proper resistance during mastication is required to deliver blood actively to the frontal lobe of the blood stream [14], and it is important to use safe exercise equipment that prevents tooth damage, as mastication is performed through the teeth and jaw joint [15]. We attempted an intervention of mastication exercises using a mouthpiece-type masticatory exercise device to prevent deterioration of cognitive function in older adults. The exercise device strengthens masticatory muscles through contraction and relaxation of the spring in the mouthpiece through a chewing motion.

The aim of this study was to examine the effect of mastication exercises, using a masticatory exercise device, on sustained attention (continuously focusing on one specific task without being disturbed), shifting attention (separating from an attention and re-concentrating on a new stimulus and working memory), temporary storage and manipulation of stimuli representations, and general cognitive function.

## 2. Methods

### 2.1. Participants

Thirty older adults living in Busan, Korea were recruited in this study. The inclusion criteria were as follows: 1) no history of neurological disorders, including brain injury, dementia, Parkinson's disease or stroke; 2) Mini-Mental State Examination (MMSE) score > 20; 3) intact function of speech and swallowing; 4) intact oral-motor structure; 5) independent ADL function; 6) the ability to understand and follow the instructions given by researcher; and 7) no visual neglect or visual field deficit. The exclusion criteria were as follows: 1) significant facial asymmetry or malocclusion; 2) communication disorder; 3) mild or moderate cognitive impairment; 4) orofacial pain, including trigeminal neuropathy and toothache; 5) history of periodontal disease; and 6) unstable respiratory function.

### 2.2. Ethics

This study was approved by Institutional Research Review Committee and the consent was obtained from all subjects (SEOUL 2019-12-019-001).

### 2.3. Intervention

The NOSICK exerciser (HIFEELWORLD Inc., Seoul, Korea) was provided to the experimental group as intervention (Fig. 1). It is a U-shaped device with three springs inside the apparatus. The springs resist to chewing movements. The covering of the equipment is covered with silicone for safe and hygienic use. Twelve subjects of them, an experimental group, used the NOSICK exerciser to perform the masticatory exercise using the following method. First, the apparatus was slipped intraorally and positioned between



Fig. 1. NOSICK exerciser.

the upper and lower teeth. Second, the subject performed masticatory exercise against the spring of the NOSICK exerciser. The exercises consisted of isometric and isotonic types, and they were performed during 15 minutes. About a 5 minute rest was provided between isometric and isotonic exercises taking muscle fatigue into consideration. The total intervention period was 6 weeks with 5 exercise periods a week. The other 13 subjects, a control group, performed daily living activities for 6 weeks without masticatory exercises using the NOSICK exerciser.

#### 2.4. Outcome measurements

Using Trail Making Test A and B, Digit Span Test forward and backward (DST-forward/backward), and Stroop test color/word, we compared the cognitive function of the subjects between before and after 6 weeks of the intervention.

#### 2.5. Statistical analyses

Analyses were undertaken using the Statistical Package for the Social Sciences (SPSS version 23). The Shapiro-Wilk test was used to test of normality and  $p$ -value of  $< 0.05$  was deemed statistically significant. The Wilcoxon signed-rank test was used to compare pre-intervention and post-intervention scores in each group. To compare intergroup changes in outcome measures, the Mann-Whitney U test was used. Cohen's  $d$ , which refers to a standardized measure of effect, was used for calculation by dividing the standardized mean difference between the two groups using the pooled standard deviation. The effect sizes of 0.2, 0.5, and 0.8 stand for a small, moderate, or large effect, respectively.

### 3. Results

#### 3.1. Characteristics of participants

A total of 30 subjects were enrolled in this study. Five of them dropped out, and the final 25 were analyzed. General characteristics of the participants are shown in Table 1. No significant difference in the general characteristics was observed between the two groups ( $p > 0.05$ ).

#### 3.2. Effect on cognitive function

In the experimental group, there were significant improvements in TMT-A/B ( $p = 0.006$  and  $0.002$ ), DST-forward ( $p = 0.001$ ), and ST-word ( $p = 0.031$ ), except DST-backward ( $p = 0.053$ ) and ST-color

Table 1  
General characteristics of participants ( $n = 25$ )

Characteristics	Experimental group ( $n = 12$ )	Control group ( $n = 13$ )
Age (year)	68.8 ± 3.2	67.5 ± 5.4
Gender ( $n$ )		
Male	4	5
Female	8	8
Number of teeth remaining	28.6 ± 2.1	27.9 ± 1.4
Education level		
Uneducated	0	0
Elementary school	6	5
Middle school	3	4
High school	2	3
University	1	1

Mean ± standard deviation.

Table 2  
Comparison of results between the two groups ( $n = 25$ )

	Experimental group ( $n = 12$ )			Control group ( $n = 13$ )			Between group $p$ value
	Pre	Post	$p$ -value	Pre	Post	$p$ -value	
TMT-A	72.29 ± 4.30	65.57 ± 4.79	0.006*	69.64 ± 4.17	68.14 ± 4.97	0.246	0.001 <sup>+</sup>
TMT-B	152.36 ± 8.85	141.14 ± 7.97	0.002*	154.5 ± 10.57	155.93 ± 15.24	0.982	0.004 <sup>+</sup>
DST-forward	3.71 ± 0.70	5.50 ± 0.50	0.001*	3.29 ± 0.80	3.79 ± 2.00	0.194	0.001 <sup>+</sup>
DST-backward	2.21 ± 0.77	3.00 ± 0.53	0.053	2.11 ± 0.53	2.43 ± 0.62	0.104	0.055
ST-word	58.57 ± 4.67	65.43 ± 4.48	0.031*	58.93 ± 5.15	60.5 ± 5.37	0.376	0.001 <sup>+</sup>
ST-color	72.36 ± 5.02	73.79 ± 4.51	0.505	70.36 ± 5.87	71.14 ± 6.94	0.701	0.305

TMT: Trail Making Test, DST: Digit Span Test, ST: Stroop test. \* $p < 0.05$  by Mann Whitney test, <sup>+</sup> $p < 0.05$  by Wilcoxon signed-rank.

( $p = 0.505$ ). On the other hand, the control group had no significant improvement ( $p > 0.05$ ). Based on comparison of the two groups after intervention phase, the experimental group showed statistical improvement in TMT-A/B ( $p = 0.001$  and  $0.004$ ), DST-forward ( $p = 0.001$ ), and ST-word ( $p = 0.001$ ), but not DST-backward ( $p = 0.055$ ) and ST-color ( $p = 0.305$ ), compared to the control group. Effect sizes were observed for the TMT-A/B (1.2 and 0.8), Digit Span Test forward/backward (0.8 and 0.2), and Stroop test color/word (0.6 and 0.2) (Table 2).

### 3.3. Reported side effect

Two out of five dropouts were due to discomfort and muscle fatigue of the chewing muscles. They reported discomfort 20 and 28 days after the start of the intervention, respectively, and immediately dropped out.

## 4. Discussion

We found that the exercises using a masticatory exercise device have a positive effect on preventing cognitive decline in individuals older than 65 years. We observed significant changes in sustained attention, shifting attention, working memory, and general cognitive function.

Mastication is defined as the act of chewing food, and the function of the masticatory system is controlled by a complex and highly precise neuro-regulatory system that acts cooperatively [16]. Several

previous studies have shown the effect of mastication on brain activation. Mastication activates several areas in humans, such as the supplementary motor area, primary sensorimotor cortex, insula, corpus striatum, thalamus, and cerebellum [17,18]. It is assumed that this brain activation is affected by information from the oral structure, including the lips, tongue, oral mucosa, teeth, and chin [19].

The Stroop test assesses selective attention, cognitive flexibility, and processing speed, while the Trail making A and B tests evaluate sustained attention and shifting attention. The rapid response time to the attention network task is associated with increased activity in the motor areas of the alerting and executive networks [20], and increased activity of the executive network is achieved by activation of the anterior cingulate cortex and left frontal gyrus [21]. Among previous studies on the effect of chewing gum on attention, an effect on sustained attention has been demonstrated [22,23]. These studies support our results. However, the effect on shifting attention remains unclear, which is not consistent with the results of this study [9,24].

Working memory refers to actively manipulating information in short-term storage through rehearsals. It pertains to the attention-related processes that are involved in managing incoming information and problem solving. In addition, long-term memory is based on relatively permanent changes from a registration of the working memory [25]. In the present study, working memory was evaluated to assess the short-term effect of masticatory exercises and, as a result, significant improvement was observed. Several studies have explored the memory effect of masticatory exercises, but the results are inconsistent. Wilkinson et al. [26] showed significantly better performance of working memory and long-term memory, while other studies reported beneficial effects of gum chewing when assessing verbal, spatial, and/or numeric working memory [27,28], supporting the results of our study. However, Smith [23] showed no significant change in short-term memory, except for immediate recall. Memory is the result of interconnection between the cerebral cortex [28], and gum chewing affects learning indirectly rather than through a direct enhancement effect. However, further studies are required.

Previous studies have reported that the degree of change in cerebral blood flow varies depending on the hardness of the chewing object or food [29]. It has been reported that moderately hard food increases cerebral blood flow, and Onozuka et al. [30] reported that masticating a moderately hard gum increased the activity of the primary sensorimotor cortex, insula and operculum than masticating a hard gum. Increased cerebral blood flow and neuronal activity may explain the increased cognition. The masticatory exercise device used in the present study is an elastic material exercise device with moderate resistance and is thought to have an effect similar to the neuronal activity of chewing moderately hard gum used in chewing gum studies.

It has been confirmed in several longitudinal studies that masticatory ability is correlated with cognitive function [31–33]. Cardoso et al. [34] reported that the Mini-Cognitive Examination scores increased with more occlusal contacts, and higher functional masticatory ability is predictive of individuals with no cognitive impairment. Lexomboon et al. [35] also found that the risk of cognitive impairment was determined not by the teeth loss but by chewing difficulty. In the present study, MMSE was used to assess general cognitive function, and a significant improvement was confirmed as a result of the intervention. Although previous studies supporting the direct causal relationship between masticatory exercise and cognitive function are not available, correlation studies on the effects on masticatory ability and cognitive function support our results.

The effects of masticatory exercise on cognitive function are mostly based on gum chewing, and the intervention used in our study has not been explored. However, previous studies on the effect of gum chewing support our results. Thus, masticatory exercises using a mouthpiece type masticatory exercise device has the potential to slow or even restore some aspects of age-related decline in working memory function and attention.

A limitation of our study was the small sample so further studies should be conducted with a larger sample. Additionally, only functional aspects of the effects of masticatory exercise were evaluated, and neurophysiological aspects such as brain activation were not assessed. We cannot confirm the long-term effects of masticatory exercise and an extended duration study is needed in the future.

## 5. Conclusions

This study demonstrated that masticatory exercises can improve cognitive function in healthy older adults. Therefore, masticatory exercises can be used as a therapeutic exercise during cognitive rehabilitation.

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## Conflict of interest

The author declares no conflicts of interest.

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