International Journal of Bio-Science and Bio-Technology
Vol.7, No.6 (2015), pp.47-54
http://dx.doi.org/10.14257/ijbsbt.2015.7.6.06

The Effects of Masticatory Exercise Using Chewing Gum on Cognitive Function and Stress

Jinhong Kim[1], Junhyuck Park[1] and Jongeun Yim[2*]

[1]*Department of Physical Therapy, Graduate School of Sahmyook University, Seoul, Republic of Korea*
[2]*Department of Physical Therapy, Sahmyook University, Seoul, Republic of Korea*
[*]*jeyim@syu.ac.kr*

Abstract

Masticatory function affects energy expenditure, heart rate, working memory, choice reaction time, and psychological arousal. In other words, masticatory function is closely related to cognitive processing ability. It also influences concentration and stress. The purpose of this study was to determine whether masticatory exercise training using chewing gum can improve cognitive function and stress. The participants were recruited from Sahmyook University and were divided into a masticatory exercise group (n = 15) and a control group (n = 15) by having each of the subjects take out one card from a box containing two types of cards representing the study groups. This study used sugar-free chewing gum with xylitol for the masticatory exercise. Cognitive function and stress were assessed before and after the masticatory exercise. The Memorizing Numbers (MN), Finding a Picture by Name (FPN), and Match Card (MC) components of the COMCOG® test were used to assess cognitive function, which is closely linked to memory, attention, and concentration. Stress was measured using the SA-3000P® system. COMCOG® component scores and stress resistance (SR) and stress index (SI) scores were assessed before and after the training. The groups significantly differed in MN, FPN, MC, SR, and SI scores ($p < 0.05$). These findings suggest that masticatory exercise using chewing gum improves cognitive function and reduces stress.

Keywords: *masticatory exercise, cognitive function, stress*

1. Introduction

Cognition is the ability to understand events taking place in the surrounding environment, assess the situation, make decisions, and adapt to the surrounding conditions. In general, it includes memory and attention at the basic level and planning, systemization, problem solving, and abstraction at the higher level. The ability to integrate sensory information, linguistic information, and visual perception information is its basis. The loss of cognitive ability results in problems in memory, calculation, judgment, orientation, understanding, etc., thereby causing considerable restrictions in daily life [1]. Mild dementia or cognitive impairment has negative effects on the patient and his or her family, such as stress and restriction on social activity [2]. Cognitive function significantly influences the recovery and rehabilitation of patients with motor functional disturbance. If cognitive function is affected, patients have difficulty in pursuing daily routines independently. Therefore, as reduced cognitive function also undermines motor functional recovery, measures to improve cognitive function play a key role in patients' recovery, rehabilitation, and independence in daily activities [3, 4].

[*] Corresponding Author

ISSN: 2233-7849 IJBSBT

In general, cognitive function problems include dementia due to neurodegenerative changes, Alzheimer's disease, and vascular dementia due to damage to the central nervous system. Alzheimer's disease is observed mainly in older people (aged 60 or over). In its initial stage, patients experience short-term memory problems, and as the disease progresses, their long-term memory and cognitive function are undermined. In vascular dementia, cognitive function problems are caused by cerebral infarction, ischemic stroke, *etc*. [4]. Twelve South Korean university hospitals examined cognitive function, including memory, judgment, and performance ability, in patients with stroke after 3 months from stroke occurrence. A total of 62.6% of the patients were found to exhibit a considerable decline in cognitive function. Most of the patients showed slight cognitive impairment (*i.e.*, daily activities were not affected) but 12.7% showed obvious cognitive decline, reaching the level of that in vascular dementia.

Alzheimer's disease or vascular dementia is a progressive disease. Researchers believe that the decline in cognitive function in this disease is ultimately unavoidable and it cannot be cured. However, with recent advances in the understanding of cases of reduced cognitive function, more systematic and scientific interventions have been attempted in individuals with a diverse spectrum of cognitive disorders [5]. Various cognitive training programs and cognitive rehabilitation methods have been utilized [6]. They can be broadly divided into measures based on physical exercise, general cognitive treatment by therapists, and computer-based cognitive rehabilitation. Exercise therapy has shown positive results in numerous areas, including stroke prevention, coronary arterial disease prevention, and reduced falls and fractures. It is also effective in improving cognitive function [7]. The general rehabilitation treatment programs by therapists and computer-based cognitive rehabilitation are effective regarding memory and attention [8]. Another research reported a positive relationship between masticatory ability and cognitive function in older people [9].

Masticatory function affects energy expenditure, heart rate, working memory, choice reaction time, and psychological arousal. In other words, masticatory function is closely related to cognitive ability [10]. It also improves concentration and alleviates stress. Studies using fMRI and PET have shown that during masticatory activity, neural activity increases in the primary somatosensory cortex, primary motor cortex, supplementary motor area, premotor area, prefrontal cortex, insula, posterior parietal cortex, thalamus, striatum, and cerebellum [11]. Masticatory activity and handgrip exercises increase middle cerebral arterial blood flow (MCAV) velocity and heart rate. Handgrip exercises have been found to increase cerebral circulation velocity on the opposite side of the hand, whereas masticatory activity has been shown to increase MCAV velocity in both sides of the brain [12].

Thus, the literature shows that masticatory activity affects brain activity and helps improve cognitive function. Accordingly, this study selected healthy participants to run a pilot study to understand the effect of masticatory activity on cognitive function and stress. It also aims to provide data that can inform treatment for patients with cognitive damage.

2. Methods

2.1. Participants

Forty healthy young adults from Sahmyook University were informed of the goals and overall protocol of this study. Of these young adults, 30 met the selection criteria and were assigned randomly to either the exercise (n=15) or control group (n=15) by having each of the subjects take out one card from a box containing two types of cards representing the study groups. We included subjects who had no previous history of facial fracture and paralysis (which could restrict jaw movement) and no history of dental disease. All protocols and procedures were approved by the Institutional Review Board of Sahmyook University (Seoul, South Korea), and all subjects gave written informed consent before the study began.\

2.2. Outcome Measures

Cognitive Function

The Computer-assisted Cognitive Rehabilitation Program (COMCOG) (Maxmedica Co., Ltd., 2004 version 1.0, ROK) was utilized (Figure 1). The program is largely divided into an attentiveness program and memory program. It has a total of 10 items each in the elementary, intermediate, and advanced levels. The rehabilitation process consists of training selection, time limit, achievement and start level change. The program is applicable appropriately for each phase depending upon memory status by using a 17-inch color monitor, COMCOG program panel and headset. In this study, it was used to assess the participants.

Match card (MC)– Playing cards are arranged in a 5 × 5 matrix. Their colors are changed to form an irregular arrangement. The participants were instructed to press the button on the left when they see three cards of the same color in a horizontal, vertical, or diagonal line. When they hear a sound, they have to press the right button. Ten trials were conducted to assess reaction time, with an accuracy of 100%.

Memorizing numbers (MN)– Six figures are presented every second. The participants have to memorize the 6 figures in reverse order and press buttons in the reverse order in which they memorized the numbers. Ten trials were conducted to assess reaction times, with an accuracy of 100%.

Finding a picture by name (FPN)– Six words are shown. Soon after, 6 pictures are added, and then, a total of 12 pictures are presented. The participants are to press the OK by finding the corresponding pictures to their six memorized words. Three trials were conducted to assess reaction time, with an accuracy of 100%.

Figure 1. Computer-Assisted Cognitive Rehabilitation Program (COMCOG)

Stress

This study used SA-6000P (Medicore Co., Ltd.) to measure stress (Figure 2). It can assess autonomic nervous system function, cardiovascular problems, stress, artery hardening, or peripheral blood circulation problems in just one round. The present study examined heart rate variability as a stress index (SI) and stress resistance (SR; evaluated by assessing the homeostasis-regulating mechanism in the autonomic nervous system against stress).

Figure2.SA-6000P

2.3. Statistical Analysis

The data were analyzed using SPSS version 18.0 for Windows (SPSS Inc., Madison, WI, USA). To compare the pre- and post-test data for the two groups, a repeated measures analysis of variance (2×2) with a between-subjects factor was used. To compare the pre–post-intervention differences between the two groups, a paired t-test was conducted. Independent t-tests were performed to compare the pre- and post-test scores and the difference by time point for the two groups. The significance threshold was 0.05

3. Results

3.1. Cognitive Function

Memorizing Numbers

MN scores significantly differed before and after exercise in both groups ($p < 0.05$) but not between the two groups ($p > 0.05$) (Table 1). In the exercise group, RTs for MN decreased from 12.91 ± 2.80 sec to 8.85 ± 1.52 sec. In the control group, they decreased from 14.29. ± 3.18 sec to 10.77 ± 2.26 sec.

Finding a Picture by Name

FPN scores significantly increased after chewing gum in the exercise group ($p < 0.05$), but not in the control group. The mean FPN score change significantly differed between the two groups ($p < 0.05$) (Table 1). FPN RTs decreased from 18.60 ± 4.60 sec to 13.06 ±

3.78 sec in the exercise group and increased from 17.93 ± 7.08 sec to 17.96 ± 10.11 sec in the control group.

Match Card

MC scores significantly increased after chewing gum in the exercise group ($p < 0.05$), but not in the control group. The mean MC score change significantly differed between the two groups ($p < 0.05$) (Table 1). MC RTs decreased from 0.83 ± 0.12 sec to 0.74 ± 0.09 sec in the exercise group and increased from 0.78 ± 0.09 sec to 0.83 ± 0.14 sec in the control group.

Table 1. Comparison of Cognitive Function Scores

		Exercise group (n = 15)	Control group (n = 15)	*t(p)*
MN (sec)	Pre	12.91±2.80	14.29±3.18	-1.259(0.218)
	Post	8.85±1.52	10.77±2.26	
	Post – pre	-4.06±1.85	-3.51±2.13	-0.748(0.461)
	t(p)	8.474(0.000)*	6.376(0.000)*	
FPN (sec)	Pre	18.60±4.60	17.93±7.08	0.309(0.759)
	Post	13.06±3.78	17.96±10.11	
	Post – pre	-5.53±3.22	0.03±4.63	0.421(0.001)*
	t(p)	6.656(0.000)*	-0.027(0.979)	
MC (sec)	Pre	0.83±0.12	0.78±0.09	1.189(0.245)
	Post	0.74±0.09	0.83±0.14	
	Post – pre	-0.08±0.10	0.04±0.15	-2.712(0.012)*
	t(p)	3.188(0.007)*	-1.176(0.259)	

Note. Values are presented as mean ± standard deviation.
MN: Memorizing Numbers, FPN: Finding a Picture by Name, MC: Match Card
* p < .05

3.2. Stress

Stress Resistance

SR significantly increased after chewing gum in the exercise group ($p < 0.05$), but not in the control group. The mean change in SR significantly differed between the two groups ($p < 0.05$) (Table 3). SR increased from 100.60 ± 10.86 to 107.93 ± 15.27 in the exercise group and decreased from 106.87 ± 14.28 to 104.00 ± 9.87 in the control group.

Stress Index

SI significantly decreased in the exercise group after chewing gum ($p < 0.05$), but not in the control group. The mean SI change significantly differed between the two groups ($p < 0.05$) (Table 3). SI decreased from 89.60 ± 7.69 to 84.87 ± 9.32 in the exercise group and increased from 89.60 ± 8.72 to 90.60 ± 7.94 in the control group.

Stress Index

SR significantly increased after chewing gum in the exercise group ($p < 0.05$), but not in the control group. The mean change in SR significantly differed between the two groups ($p < 0.05$) (Table 3). SR increased from 100.60 ± 10.86 to 107.93 ± 15.27 in the exercise group and decreased from 106.87 ± 14.28 to 104.00 ± 9.87 in the control group.

Table 2. Comparison of Stress

		Exercise group (n = 15)	Control group (n = 15)	*t(p)*
ST (score)	Pre	100.60±10.86	106.87±14.28	-1.352(0.187)
	Post	107.93±15.27	104.00±9.87	
	Post – pre	7.33±11.67	-2.87±12.05	2.354(0.026)*
	t(p)	-2.433(0.029)*	0.921(0.373)	
SI (score)	Pre	89.60±7.69	89.60±8.72	0.000(1.000)
	Post	84.87±9.32	90.60±7.94	
	Post – pre	-4.73±6.47	0.80±5.01	-2.616(0.014)*
	t(p)	2.831(0.013)*	-0.306(0.764)	

Note. Values indicate mean ± standard deviation.
ST: Stress resistance, SI: Stress index.
* p < .05

4. Discussion

Impaired cognitive function due to central nervous system diseases, including traumatic injury, stroke and neurodegenerative disorders, is closely related to brain damage and functional recovery [13]. Studies using fMRI have shown that cognitive treatment performed for patients with cognitive damage activates all neural regions related to memory [14]. Historically, therapeutic interventions to treat cognitive problems resulting from brain damage include natural recovery, general methodological cognitive treatment, and treatment based on compensatory approaches [15]. The research team of Japan's Tohoku University reported recently that tooth health affected brain cognitive function. People with better masticatory ability experience larger blood flow to cerebrum to increase memory transmitters and the cells in hippocampus of cerebral temporal lobe which manage memory and learning ability. As a result, grain cognitive function is positively affected. According to Xi chen, *et al.*, (2013), chewing gums reduces the activity of stress-related brain parts while decreasing cortisol secretion, a stress-related hormone [16].

Against this background, the present study hypothesized that masticatory exercise would promote cognitive function and reduce stress. Participants were divided into an exercise group and a control group to determine the effect of masticatory exercise on memory, attention, and stress.

Computer-assisted cognitive rehabilitation was reported to noticeably improve memory, problem-solving ability, and attention in patients with brain damage [17].

Another study reported that cognitive function improved after repeated bouts of training in which the difficulty level of cognitive tests was gradually increased, on the basis of the neural plasticity theory [18]. In yet another study, computer-assisted cognitive rehabilitation was found to improve diverse aspects of cognition in patients with brain damage, whereas the control group receiving conventional treatment did not show such improvements [19]. Physical activity, that is, exercise, has a positive effect on cognitive function [20]. A recent study reported that patients who had undergone non-aerobic but movement-based exercise therapy for 6 weeks showed better concentration, visual memory, and working memory than the control group. Another study found that muscle-strengthening exercise helped improve cognitive function [18]. Diverse cognitive therapeutic interventions have been applied in clinical settings. According to previous studies, a single intervention may not be effective since patients exhibit diverse symptoms such as reduced cognitive function and abnormal behavioral intentions; complex multi-disciplinary interventions have been found to be effective [3].

In this study, the exercise group showed significant improvements in the MN, FPN, and MC tasks whereas the control group showed a significant improvement in only MN. Post-intervention improvements in FPN and MC performance significantly differed between the exercise group and control group [21]. These results can be attributed to the positive effect of masticatory exercise on memory and attention. SR and SI scores also significantly improved in only the exercise group, and the post-intervention changes in these variables significantly differed between the exercise group and control group. This finding can be attributed to the positive effect of masticatory exercise on stress relief. On the basis of the above findings, masticatory exercise can be said to improve cognitive function and alleviate stress. However, this study is limited in that the sample consisted of adults without cognitive impairments and the size of the intervention group was small. Its intervention period was short and intervention frequency was comparatively low. Future studies should include patients with cognitive impairments in their samples as well as increase the duration and frequency of the intervention.

Acknowledgements

This study was supported by Sahmyook University

References

[1] T. W. McAllister, "Cognitive functioning in the affective disorders", Compr Psychiatry, vol. 6, no. 22, **(1981)**.

[2] D. B. Hogan, P. Bailey, S. Black, A. Carswell, H. Chertkow, B. Clarke, C. Cohen, J. D. Fisk, D. Forbes, M. Man-Son-Hing, K. Lanctot, D. Morgan and L. Thorpe, "Diagnosis and treatment of dementia: 4", Approach to management of mild to moderate dementia. CMAJ, vol. 8, no. 179, **(2008)**.

[3] S. C. Burgener, L. L. Buettner, E. Beattie and K. M. Rose, "Effectiveness of community-based, nonpharmacological interventions for early-stage dementia: conclusions and recommendations", J Gerontol Nurs, vol. 3, no. 35, **(2009)**.

[4] F. Yu, K. M. Rose, S. C. Burgener, C. Cunningham, L. L. Buettner, E. Beattie, A. L. Bossen, K. C. Buckwalter, D. M. Fick, S. Fitzsimmons, A. Kolanowski, K. Janet, P. Specht, N. E. Richeson, I. Testad and S. E. McKenzie, "Cognitive training for early-stage Alzheimer's disease and dementia", J Gerontol Nurs, vol. 3, no. 35, **(2009)**.

[5] D. B. Hogan, P. Bailey, S. Black, A. Carswell, H. Chertkow, B. Clarke, C. Cohen, J. D. Fisk, D. Forbes, M. Man-Son-Hing, K. Lanctot, D. Morgan and L. Thorpe, "Diagnosis and treatment of dementia: 5", Nonpharmacologic and pharmacologic therapy for mild to moderate dementia. CMAJ, vol. 10, no. 179 **(2008)**.

[6] A. Bahar-Fuchs, L. Clare and B. Woods, "Cognitive training and cognitive rehabilitation for mild to moderate Alzheimer's disease and vascular dementia", Cochrane Database Syst Rev., vol. 6, **(2013)**.

[7] M. P. Mattson, "Energy intake and exercise as determinants of brain health and vulnerability to injury and disease", Cell Metab, vol. 6, no. 16, **(2012)**.

[8] T. Vogel, P. H. Brechat, P. M. Lepretre, G. Kaltenbach, M. Berthel and J. Lonsdorfer, "Health benefits of physical activity in older patients: a review", Int J Clin Pract, vol. 2, no. 63, **(2009)**.

[9] R. A. Weijenberg, E. J. Scherder and F. Lobbezoo, "Mastication for the mind--the relationship between mastication and cognition in ageing and dementia", Neurosci Biobehav Rev, vol. 3, no. 35, **(2011)**.
[10] A. Smith, "Effects of chewing gum on cognitive function, mood and physiology in stressed and non-stressed volunteers", Nutr Neurosci, vol. 1, no. 13, **(2010)**.
[11] N. Narita, K. Kamiya, K. Yamamura, S. Kawasaki, T. Matsumoto and N. Tanaka, "Chewing-related prefrontal cortex activation while wearing partial denture prosthesis: pilot study", J Prosthodont Res, vol. 3, no. 53, **(2009)**.
[12] T. Ono, Y. Hasegawa, K. Hori, T. Nokubi and T. Hamasaki, "Task-induced activation and hemispheric dominance in cerebral circulation during gum chewing", J Neurol, vol. 10, no. 254, **(2007)**.
[13] M. Ylvisaker, R. Hanks and D. Johnson-Greene, "Perspectives on rehabilitation of individuals with cognitive impairment after brain injury: rationale for reconsideration of theoretical paradigms", J Head Trauma Rehabil, vol. 3, no. 17, **(2002)**.
[14] L. G. Gagnon and S. Belleville, "Training of attentional control in mild cognitive impairment with executive deficits: results from a double-blind randomised controlled study", Neuropsychol Rehabil, vol. 6, no. 22, **(2012)**.
[15] L. Clare, "Awareness in early-stage Alzheimer's disease: a review of methods and evidence", Br J Clin Psychol.Pt, vol. 2, no. 43, **(2004)**.
[16] H. Yu, X. Chen, J. Liu and X. Zhou, "Gum chewing inhibits the sensory processing and the propagation of stress-related information in a brain network", PLoS One, vol. 4, no. 8, **(2013)**.
[17] Z. B, "Prevention strategies targeting different preclinical stages of Alzheimer's disease", Curr Alzheimer Res., **(2015)**.
[18] L. Yaguez, K. N. Shaw, R. Morris and D. Matthews, "The effects on cognitive functions of a movement-based intervention in patients with Alzheimer's type dementia: a pilot study", Int J Geriatr Psychiatry, vol. 2, no. 26, **(2011)**.
[19] S. H. Chen, J. D. Thomas, R. L. Glueckauf and O. L. Bracy, "The effectiveness of computer-assisted cognitive rehabilitation for persons with traumatic brain injury", Brain Inj, vol. 3, no. 11, **(1997)**.
[20] J. G. van Uffelen, A. P. M. J. Chin, M. Hopman-Rock and W. van Mechelen, "The effects of exercise on cognition in older adults with and without cognitive decline: a systematic review", Clin J Sport Med, vol. 6, no. 18, **(2008)**.
[21] S. J. Cho, "Current Research Trend of Bioscience and Welfare III", Proceedings of the Internatioal Workshop Bioscience and Medical Research, **(2015)**, Jeju, Korea.

