

Continuous Gum Chewing Exercise Improves Perioral Muscle Strength

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Abstract

Objective: The purpose of this study was to examine the effects of continuous gum chewing exercise on perioral muscle strength. **Methods:** Thirty healthy adults (24.1 ± 2.0 years) with normal occlusion performed gum chewing exercise 3 times daily for 3 months. Each exercise session lasted 5 min and involved alternating of chewing 10 times using the left molars and then 10 times using the right molars, with the mouth closed. The effect of the exercise on oral function was evaluated by measuring tongue pressure (TP), cheek pressure (CP), and labial closure strength (LCS) immediately before starting exercise, at 2 weeks and 1, 2, and 3 months after starting exercise, and at 3 months after cessation of exercise. Changes in TP, CP, and LCS according to sex and duration of exercise were analyzed by repeated two-way ANOVA. **Results:** Measurements for all muscles were significantly greater in men than in women at all time points. After starting exercise, TP was markedly increased at 2 months in men and women, and both CP and LCS were markedly increased at 2 weeks in men and at 1 month in women. These effects persisted for 3 months. Three months after cessation of exercise, TP, CP, and LCS tended to decrease, but were not significantly attenuated as compared with 3 months after beginning of exercise in either sex. **Conclusion:** The results of this study revealed that gum chewing exercise contributed to an improvement in perioral muscle strength, and that this effect was maintained for at least 3 months after discontinuation of exercise.

Keywords

Oral Function, Gum Chewing Exercise, Tongue Pressure, Cheek Pressure, Labial Closure Strength

1. Introduction

Life expectancy is increasing year after year around the world, and World Health Statistics 2023 shows that 31 countries are experiencing population aging, with an average life expectancy of over 80 years [1]. However, the difference between life expectancy and healthy life expectancy (*i.e.*, the period during which independent living can be sustained) is about 10 years in these countries. Hence, many countries face a variety of challenges, including increased costs for social security and nursing care and a shrinking labor force. Extending the healthy life span is an important goal in terms of improving people's quality of life and reducing their medical and long-term care expenses. General health is strongly affected by the oral environment [2], such as the number of remaining teeth, occlusal support, and swallowing function. For example, a reduction in the number of teeth decreases the area of occlusal support and affects the balance sense of the body in elderly. And as the lower limb muscles weaken as the age progresses and walking ability declines. If the deterioration of the balance sense and the reflexes overlap with this, which increases the risk of falls and the likelihood of becoming bedridden after a femoral fracture. Furthermore, the reflexes deteriorate with age, which increases the risks of choking, aspiration, and aspiration pneumonitis. One of these factors is the strength of the intraoral and extraoral muscles that assist the function of the teeth and jaw during mastication. It has also been reported that the strength of the tongue and lip muscles is important for improving the quality of oral function in healthy individuals [3].

There have been many reports on using perioral muscle strength, especially tongue pressure (TP), to objectively evaluate oral function [4]-[8]. In an earlier study, we evaluated TP and cheek pressure (CP) with a tongue pressure measuring device, labial closure strength (LCS) with a perioral muscle pressure measuring device, and masticatory ability with gummy jelly [9]. This found that TP was a reliable indicator of oral function that could be measured simply and rapidly with good reproducibility.

In recent years, there has been an increasing amount of research focused on how to improve oral function [3] [5] [8] [10]-[14], which has mainly involved improving tongue movement or using special equipment. There are various subjects such as those aimed at improving the oral function of the elderly, or those aiming at the development of the jaw and the mastication guidance of children. It has been reported that these exercises can increase TP, LCS, and masticatory ability [3] [5] [8] [10]-[14]. The purpose of this study was to examine the effects of continuous gum chewing exercise on the perioral muscles through TP, CP, and LCS.

2. Materials and Methods

This study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-H-154). The details of the study were described

in full to all participants, and their written informed consent was obtained.

This study was conducted in accordance with the PRILE 2021 guidelines (**Figure 1**) [15].

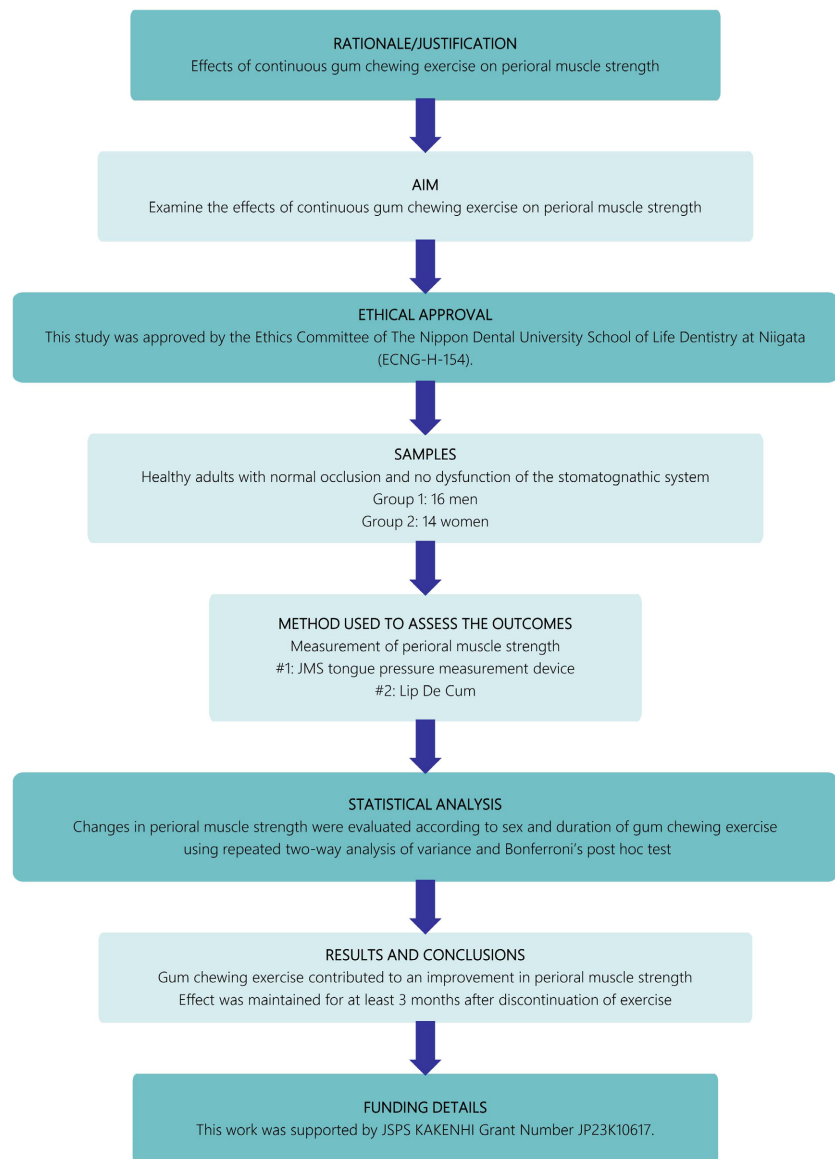


Figure 1. Research design flowchart.

2.1. Participants

The participants were 30 healthy adults (16 men, 14 women; mean age 24.1 ± 2.0 years) with normal occlusion and no subjective or objective morphological or functional abnormalities in the stomatognathic system.

2.2. Gum Chewing Exercise

Participants were instructed to chew 2 pieces of gum (Dentzyme Q10[®], Tokyo Shizaisya Co., Tokyo, Japan) (**Figure 2**) in each exercise session, conducted 3

times daily for 3 months. Each exercise session lasted 5 min and involved alternating chewing cycles of chewing 10 times using the left molars and then 10 times using the right molars, with the mouth closed.

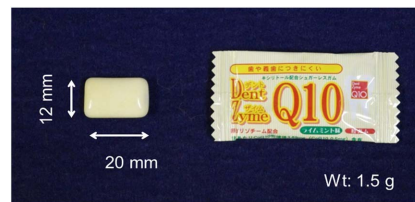


Figure 2. Chewing gum.

2.3. Measurement of Perioral Muscle Strength

TP and CP were measured using a JMS tongue pressure measurement device[®] (JMS Co., Hiroshima, Japan) (Figure 3) [7]-[9]. The probe was inflated with air at a baseline pressure of 19.6 kPa. After offsetting this baseline value to 0 kPa, pressure applied to the probe was recorded as the change in its internal pressure. To measure TP, the balloon was positioned on the anterior palate with the lips closed. The participants then raised their tongue and compressed the balloon onto the palate with maximal voluntary effort for approximately 7 s. To measure CP, the balloon was positioned in the space between the upper and lower first molars and the buccal mucosa on the habitual chewing side. The participants then closed their lips and compressed the balloon against the buccal surface of the molars with maximal voluntary effort for approximately 5 s. LCS was measured using the Lip De Cum[®] (Cosmo Instruments, Tokyo, Japan) (Figure 4) [7] [8]. In a sitting position with the Frankfurt plane parallel to the floor, participants gripped the sensor between the lips and closed the lips for 5 s with maximum strength without clenching the teeth. The mean of 3 recordings separated by rest intervals of 30 s was used in the analysis. Measurements were taken immediately before starting exercise, at 2 weeks and 1, 2, and 3 months after starting exercise, and at 3 months after cessation of exercise.

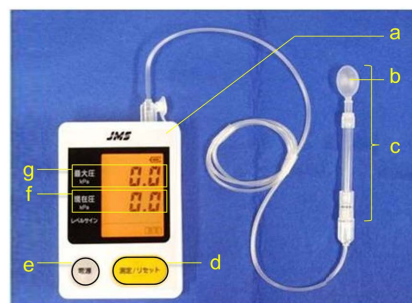


Figure 3. Balloon-based tongue pressure measurement device (JMS tongue pressure measurement device[®]). (a) Digital tongue pressure measurement device; (b) Balloon (width: 18 mm; height: 25 mm); (c) Disposable probe; (d) Measurement/reset; (e) Power; (f) Present pressure; (g) Maximum pressure.



Figure 4. Labial closure strength measurement device (Lip De Cum®). (a) Digital labial closure strength measurement device; (b) Sensor; (c) Holding part (Duckling®).

2.4. Statistical Analysis

Data were analyzed using SPSS version 24 software (SPSS Japan Inc., Tokyo, Japan). Changes in TP, CP, and LCS were evaluated according to sex and duration of gum chewing exercise. The Shapiro-Wilk test was used to examine normality, and Mauchly's sphericity test was used to examine equality of variance among the study parameters. Normality was found for all parameters but the assumption of sphericity was not satisfied, so the Greenhouse-Geisser correction was applied. All analyses were performed using repeated two-way analysis of variance and Bonferroni's post hoc test. A P-value < 0.05 was considered statistically significant.

3. Results

Tables 1-3 show the results of repeated two-way ANOVA for changes in TP, CP, and LCS based on sex differences and duration of exercise. TP, CP, and LCS showed significant differences by sex and measurement point, but there was no interaction between these factors.

Table 1. Results of repeated two-way ANOVA for change in tongue pressure according to sex and duration of gum chewing exercise.

Source	SS	df	MS	F value	P value
Sex difference					
A	10494.985	1	10494.985	62.433	<0.001**
Error (A)	4706.781	28	168.099		
Duration of exercise					
B	658.769	1.673	393.674	16.871	<0.001**
A × B	19.239	1.673	11.497	0.493	0.581
Error (B)	1093.310	46.855	23.334		

SS, sum of squares; df, degrees of freedom; MS, mean square; **P < 0.01, denotes statistical significance.

Table 2. Results of repeated two-way ANOVA for change in cheek pressure according to sex and duration of gum chewing exercise.

Source	SS	df	MS	F value	P value
Sex difference					
A	4480.800	1	4480.800	11.207	<0.01**
Error (A)	11194.855	28	399.816		
Duration of exercise					
B	410.859	1.949	210.788	29.981	<0.001**
A × B	32.544	1.949	16.696	2.375	0.104
Error (B)	383.712	54.576	7.031		

SS, sum of squares; df, degrees of freedom; MS, mean square; **P < 0.01, denotes statistical significance.

Table 3. Results of repeated two-way ANOVA for change in labial closure strength according to sex and duration of gum chewing exercise.

Source	SS	df	MS	F value	P value
Sex difference					
A	745.454	1	745.454	28.475	<0.001**
Error (A)	733.028	28	26.180		
Duration of exercise					
B	122.332	3.302	37.043	28.102	<0.001**
A × B	1.308	3.302	0.396	0.300	0.843
Error (B)	121.888	92.469	1.318		

SS, sum of squares; df, degrees of freedom; MS, mean square; **P < 0.01, denotes statistical significance.

Tables 4-6 and **Figures 5-7** show the results of the multiple comparison analysis for the change in strength for each of the perioral muscles. Measurements for all muscles were significantly higher in men than in women. TP showed significant differences at 2 months after starting exercise in both men and women, with increases to 6.2 kPa (13.2%) and 5.1 kPa (16.1%) at 3 months after starting exercise, respectively. CP showed significant differences at 2 weeks after starting exercise in men and 1 month after starting exercise in women, with increases to 5.6 kPa (30.3%) and 3.4 kPa (27.9%) at 3 months after starting exercise, respectively. Likewise, LCS showed significant differences at 2 weeks after starting exercise in men, and 1 month after starting exercise in women, with increases to 2.7 kPa (17.7%) and 2.4 kPa (22.0%), respectively, at 3 months after starting exercise. Three months after cessation of exercise, TP, CP, and LCS tended to decrease, but the measurements remained significantly higher than those before exercise in

both sexes. TP was similar at 3 months in both sexes, and CP and LCS were similar at 2 months in men and at 1 month in women.

Table 4. Results of multiple comparison analysis of the change in tongue pressure at each measurement point in gum chewing exercise for men and women.

		Before exercise		2 weeks		1 month		2 months		3 months	
		Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Before exercise	Men	—	—	—	—	—	—	—	—	—	—
	Women	—	—	—	—	—	—	—	—	—	—
2 weeks	Men	n.s.	—	—	—	—	—	—	—	—	—
	Women	—	n.s.	—	—	—	—	—	—	—	—
1 month	Men	n.s.	—	n.s.	—	—	—	—	—	—	—
	Women	—	n.s.	—	n.s.	—	—	—	—	—	—
2 months	Men	*	—	n.s.	—	n.s.	—	—	—	—	—
	Women	—	**	—	n.s.	—	n.s.	—	—	—	—
3 months	Men	**	—	**	—	*	—	n.s.	—	—	—
	Women	—	**	—	**	—	n.s.	—	n.s.	—	—
Discontinuation of exercise	Men	**	—	*	—	n.s.	—	n.s.	—	n.s.	—
	Women	—	**	—	*	—	n.s.	—	n.s.	—	n.s.

n.s., not statistically significant. *P < 0.05, **P < 0.01.

Table 5. Results of multiple comparison analysis of the change in cheek pressure at each measurement point in gum chewing exercise for men and women.

		Before exercise		2 weeks		1 month		2 months		3 months	
		Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Before exercise	Men	—	—	—	—	—	—	—	—	—	—
	Women	—	—	—	—	—	—	—	—	—	—
2 weeks	Men	**	—	—	—	—	—	—	—	—	—
	Women	—	n.s.	—	—	—	—	—	—	—	—
1 month	Men	**	—	**	—	—	—	—	—	—	—
	Women	—	**	—	n.s.	—	—	—	—	—	—
2 months	Men	**	—	**	—	n.s.	—	—	—	—	—
	Women	—	**	—	*	—	n.s.	—	—	—	—
3 months	Men	**	—	**	—	**	—	n.s.	—	—	—
	Women	—	**	—	**	—	n.s.	—	n.s.	—	—
Discontinuation of exercise	Men	**	—	**	—	n.s.	—	n.s.	—	n.s.	—
	Women	—	**	—	n.s.	—	n.s.	—	n.s.	—	n.s.

n.s., not statistically significant. *P < 0.05, **P < 0.01.

Table 6. Results of multiple comparison analysis of the change in labial closure strength at each measurement point in gum chewing exercise for men and women.

		Before exercise		2 weeks		1 month		2 months		3 months	
		Men	Women	Men	Women	Men	Women	Men	Women	Men	Women
Before exercise	Men	—	—	—	—	—	—	—	—	—	—
	Women	—	—	—	—	—	—	—	—	—	—
2 weeks	Men	**	—	—	—	—	—	—	—	—	—
	Women	—	n.s.	—	—	—	—	—	—	—	—
1 month	Men	**	—	n.s.	—	—	—	—	—	—	—
	Women	—	**	—	n.s.	—	—	—	—	—	—
2 months	Men	**	—	n.s.	—	n.s.	—	—	—	—	—
	Women	—	**	—	n.s.	—	n.s.	—	—	—	—
3 months	Men	**	—	**	—	n.s.	—	n.s.	—	—	—
	Women	—	**	—	n.s.	—	n.s.	—	n.s.	—	—
Discontinuation of exercise	Men	**	—	n.s.	—	n.s.	—	n.s.	—	n.s.	—
	Women	—	**	—	n.s.	—	n.s.	—	n.s.	—	n.s.

n.s., not statistically significant. **P < 0.01.

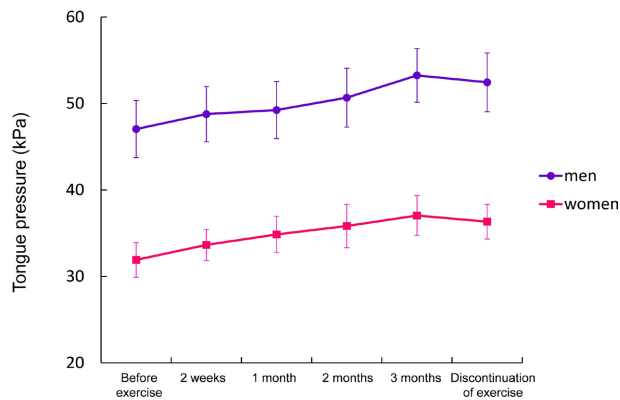


Figure 5. Changes in tongue pressure (mean ± 1 S.D.) based on duration of gum chewing exercise in both men and women.

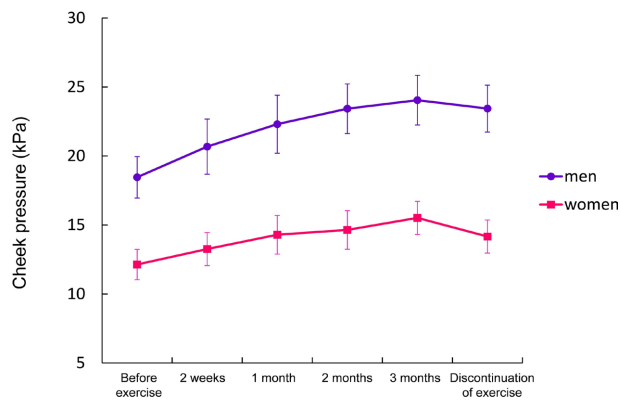


Figure 6. Changes in cheek pressure (mean ± 1 S.D.) based on duration of gum chewing exercise in both men and women.

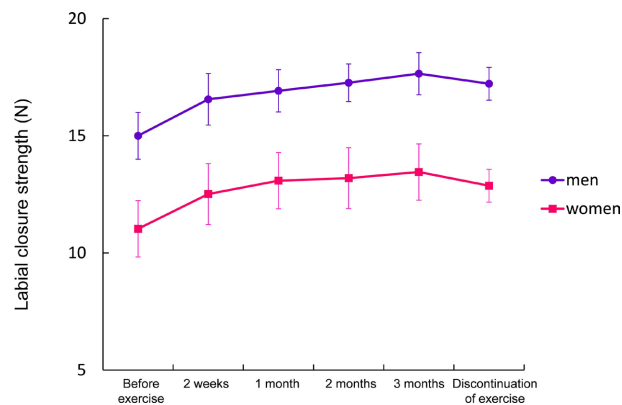


Figure 7. Changes in labial closure strength (mean \pm 1 S.D.) based on duration of gum chewing exercise in both men and women.

4. Discussion

The effect of a functional oral training program depends on the target's background. In children, such programs are selected to promote occlusion in the presence of healthy dentition [13] [14], while in adults they may be used to reduce sagging of the face and enrich facial expression [4] [16]. Oral training may also be implemented in the elderly to preserve swallowing and masticatory functions [10]. In addition to the above-mentioned applications, there have been reports of changes in the form and function of oral tissues after functional oral training, including increases in tongue volume, TP, and amount of saliva secretion, as well as improvement of dysphagia [3] [5] [10] [11] [13] [14] [16]. On the other hand, in sports, several studies have reported that stomatognathic function affects motor function; bite force and bite balance are related to agility, muscle strength, and jumping ability, and affect cutting movements and balance ability [17]-[22].

Mastication is an oral activity that is performed on a daily basis. However, chewing on only one side, chewing with the mouth open, and swallowing without adequate chewing can lead to the decrease tongue and lip muscle strength, the developmental disorders of the jaw, the asymmetry of maxillofacial, and the imbalance in oral function, all of which can greatly affect quality of life [16] [23]. The purpose for gum chewing exercise in healthy adults are four-fold: 1) Correction of habitual chewing on one side; 2) Strengthening the tongue and cheek muscles involved in mastication; 3) Improvement of LCS by correcting chewing with the mouth open, which has become increasing with the increase of soft foods in recent years; 4) Improvement of physical functions in sports. To accomplish these three objectives, we devised a program that uses a chewing gum in how to masticate evenly using the left and right molars and with the mouth closed for a set period of time. Use of chewing gum in such a program has the advantages of not needing any special equipment or materials, being easy to incorporate into everyday life, and using a familiar confectionery item.

There are three points of the program of gum chewing exercise in this study: 1) Alternating chewing of 10 times using the left molars and then 10 times using the

right molars for 5 min; 2) Maintaining with the mouth closed; 3) Perform 3 times daily for 3 months. The above 1) is because it is to avoid the chopping stroke. When gum is chewed continuously for a long time, the temporal muscles responsible for chopping become overworked and that caused muscle pain and temporomandibular joint disorders [23]. And distorted facial features due to excessively prolonged chewing has also been reported [23]. Consequently, the participants were instructed to undertake gum chewing exercise for 5 min only, and not to chew for a long time. The above 2) is because there is a possibility to cause mouth respiration if gum chewing continues without mouth closed. The above 3) was set for the following reasons. The muscles involved in gum chewing are the same as those involved in eating; hence the practice would be easy to continue by habituation because the load on the muscles due to exercise is small and the burden on the participants is also small. However, because the load per time is small, continued exercise is necessary for the effects to appear. Therefore, the frequency of exercise sessions was set at 3 times daily and the duration at 3 months. However, we did not stipulate that the sessions should be performed at specific times of the day and we did not set a masticatory rhythm. The only specific instructions provided were to alternate chewing for 10 strokes on each side for 5 min, 3 times daily for 3 months. In view of report on the activity of the masseter and orbicularis muscles during gum chewing suggesting that approximately 3 - 4 g of gum is suitable for functional training [16], we instructed participants to chew two 1.5 g pieces of gum per exercise session in this study.

The measurements obtained before exercise were similar to those previously reported for healthy adults aged 20 - 30 years [6]-[8], indicating that the study sample was representative of the general population. In addition, similar to the above, sex difference was recognized, and men showed higher values than women. This is due to the difference in total muscle mass depending on gender [6] [11] [23], the same tendency was shown for the perioral muscle strength as a result of this study.

The time of onset of the effect of gum chewing exercise conducted in this study, TP was observed after 2 months in both sexes, and both CP and LCS were observed after 2 weeks for men and 1 month for women, respectively. Increases in TP occurred later than that of functional training targeted to healthy adults reported so far [5] [8] [11]. This is probably because gum chewing is a repetition of a simple exercise in which the range of tongue movement is narrower than that of chewing during everyday meals, so the burden on the tongue is small. In the first stage of mastication, the food is cut by the anterior teeth when it enters the mouth and is then transferred to either the left or right molar area using the tongue. In the second stage, during which the food is crushed, food falling to the lingual and buccal side accompanying is placed between the upper and lower molars again with the tongue and cheeks and the food is repeatedly grinding and mixed with saliva to form a bolus. In the third stage, the bolus is carried to the pharynx by the tongue and swallowing occurs. Gum chewing exercise is an exercise that includes

the first and second stages. Since the mass of the chewing gum is relatively small and movement to the opposite molar teeth for chewing is repeated, it is presumed that the tongue and cheek are constantly under tension during the 5 min of exercise. Therefore, although the exercise load was small, we judged that an effect of exercise would be clearly demonstrated. These observations indicate that the oral function exercise that maintains with mouth closed for a certain period of time can be expected to raise CP and LCS which are not mainly moving muscles. Increases in these parameters might be useful for strengthening the facial muscles. The change in these measurements 3 months after cessation of gum chewing exercise were not significantly different from those recorded after 3 months after exercise, even though the effect of the exercise appeared slowly. Therefore, we can assume that this method imposes very little burden on participants and is easy to continue.

This study has two main limitations. The first is that the participants were limited to healthy adults. The effects of oral function exercises and their onset timing are likely to be influenced by the health condition and age of the participants [3] [8] [10] [24], and in addition, denture wearers may have difficulty chewing gum. Second, there was no long-term study after exercise was stopped, so it was not possible to determine how long the effects of exercise lasted. It would be necessary to consider the effects of this exercise in consideration of the age and health condition of the participants.

5. Conclusion

The results of this study revealed that gum chewing exercise in healthy adults contributed to an improvement in perioral muscle strength, and that this effect was maintained for at least 3 months after discontinuation of exercise. In the future, we plan to verify the effectiveness of this exercise in athletes and clarify its impact on balance ability and motor function.

Acknowledgements

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Conflicts of Interest

The authors have no conflicts of interest relevant to this article.

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