



Original Article

Effects of gum chewing training on oral function in normal adults: Part 1 investigation of perioral muscle pressure

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KEYWORDS

Swallowing and feeding function;
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Cheek pressure

Abstract *Background/purpose:* The strength of the intraoral and extraoral muscles that assist the function of tooth and jaw movement during mastication is important for performing oral function. The aim of this study was to investigate the usefulness of gum chewing training to improve the swallowing and feeding function.

Materials and methods: In experiment 1, the differences in maximum tongue pressure (TP) and cheek pressure (CP) at the measurement time point for both groups with and without training were examined. We instructed subjects to perform gum chewing training 3 times daily for 3 months. TP and CP were measured before training and at 1, 2, and 3 months after starting training. In experiment 2, the changes of TP and CP based on the sex and duration of training were examined. The effect of the training was evaluated before training, at 2 weeks and 1, 2, and 3 months after starting training, and at 1 and 3 months after cessation of training.

Results: Experiment 1 showed TP and CP increased with the progress of continuous training. In experiment 2, TP and CP were higher in men than in women and markedly increased at 2 weeks and 1 month in both sexes. After cessation of training, TP and CP tended to decrease, but there was no significant difference between 3 months after starting training, and also significantly higher than before training.

Conclusion: This study suggested that gum chewing training is a useful to improve the swallowing and feeding function.

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Introduction

The masticatory process involves rhythmic opening and closing of the jaw and the coordinated movements of tongue, cheeks and lips,^{1,2} which can be generated by the central pattern generator in the brain stem.³ During mastication, the tongue and cheeks cooperate to hold food on the dentition and grind with upper and lower teeth so that food does not fall outside the dentition. In addition, the tongue serves to transfer the food to the left and right of the molars during chewing. When the food is thoroughly ground, the bolus is collected by cooperative movement of the tongue and cheeks and sent to the pharynx by movement of the tongue. The strength of the intraoral and extraoral muscles that assist the function of tooth and jaw movement during mastication is important for performing oral function.⁴ In particular, significant tongue pressure is needed to form a bolus in the preparatory and oral stages of swallowing, and to pass it to the pharynx.⁵ In recent years, there have been reports on the decline of perioral muscle strength (i.e. tongue, cheeks, and lips), developmental disorders of the jaw, maxillofacial asymmetry, and imbalance in oral function.^{6–8} These problems may be related to unilateral chewing and decreases in chewing number, and would be influenced by an increase in soft food.

There have been many reports on using perioral muscle strength, namely tongue pressure (TP), cheek pressure (CP), and lip closure strength, to objectively evaluate oral function.^{6,9–14} In a previous study, we evaluated the reliability of the measured value using a tongue pressure measurement device.¹² This study found that TP and CP were reliable indicators of oral function that could be measured simply and rapidly (about 5–7 s) with good reproducibility.

Various programs have been attempted for the purpose of improving oral function.^{4,15–23} The effect of a functional training program depends on subject background. In children, such programs are selected to promote occlusal condition and improvement of masticatory performance,^{15,21} while in adults, they may be used to reduce sagging of the face, enrich facial expression, skin elasticity, and occlusal contact area and force.^{4,18} Oral training may also be performed in the elderly people to prevent deterioration of swallowing function and masticatory ability.^{16,22,23} It has been reported that such training can increase tongue strength, labial closure strength, and masticatory ability.^{4,6,9,15,19–22} In addition, there have been reports of changes in the form and function of oral tissues after oral functional training, including increases in tongue volume and improvement of dysphagia.^{16,17} It is desirable that the effect of oral functional training should be maintained even after cessation of training. However, the effect of this training for normal adults has been shown to decrease again after cessation.^{18,19} On the other hand, Arakawa et al.⁶ reported that it was necessary to continue for more than 2 months to stabilize the muscle strengthened by tongue rotation exercise training, but evaluation after cessation of training was not performed. It therefore remains uncertain when effects of training will manifest and whether the effects are maintained after cessation of training.

The aim of this study were to investigate the hypothesis that gum chewing training including chewing guidance could improve the swallowing and feeding function and to evaluate whether the effects continue even after cessation of training. Cooperative movements of the tongue and cheek are performed during swallowing and feeding, so the effect of training was objectively evaluated by measurement of TP and CP. In this study, gum chewing training was conducted in normal adults as a pilot study to establish an effective program for improving oral function. We ultimately plan to utilize this training to improve the swallowing and feeding function in the elderly and in patients with swallowing and feeding difficulty.

Materials and methods

Experiment 1

Subjects

Subjects were 24 healthy adults with normal occlusion and no dysfunction of the stomatognathic system. They were divided into two groups; the training group (12 men, mean age 24.4 ± 1.9 years), and the control group (12 men, mean age 24.3 ± 2.1 years). Subjects were sampled by via advertisement from a campus, and they were screened for oral dysfunction by a dentist.

Gum chewing training

We instructed subjects in the training group to chew two pieces of hard chewing gum (DAY-UP; LION Co., Tokyo, Japan)¹⁵ in each training session, conducted 3 times daily for 3 months. Each training session lasted for 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. The method of training was demonstrated after instruction from a dentist using text materials. A checklist was distributed to subjects, and the number of training sessions, the time per session, and the mastication method were checked it yourself every day and confirmed every two weeks by a dentist, and training implementation and appropriateness were evaluated. The control groups were given no task.

Measurement of perioral muscle strength

TP and CP were measured using a tongue pressure measurement device (JMS tongue pressure measurement device; JMS Co., Hiroshima, Japan) (Fig. 1).^{6,10–12} The mean of three recordings separated by rest intervals of 1 min was used in the analysis. Measurements were taken just before starting training and at 1, 2, and 3 months after starting training.

Experiment 2

Subjects

Subjects were 32 healthy adults (18 men; mean age 24.0 ± 2.2 years, 16 women; mean age 24.3 ± 1.9 years) with normal occlusion and no dysfunction of the stomatognathic system. Independent groups of subjects were recruited for each experiment. As in Experiment 1, subjects

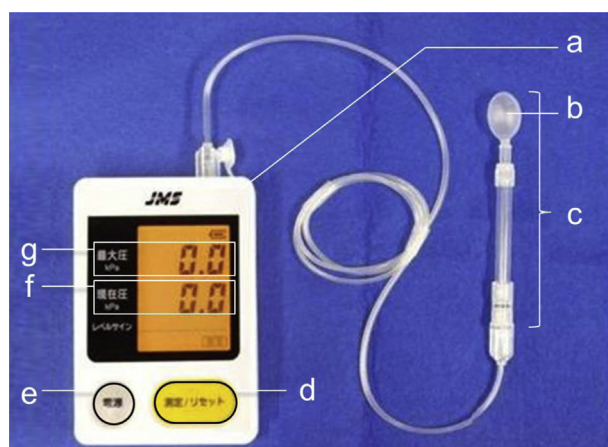


Fig. 1 Balloon-based tongue pressure measurement device (JMS tongue pressure measurement device). (a) digital tongue pressure measurement device; (b) balloon (width: 18 mm; height: 25 mm); (c) disposable probe; (d) measurement/reset; (e) power; (f) present pressure; (g) maximum pressure.

were sampled via advertisement from a campus, and they were screened for oral dysfunction by a dentist.

Practice of gum chewing training and measurement of TP and CP

As in Experiment 1, subjects were instructed to perform gum chewing training 3 times daily for 3 months. We measured TP and CP before training, at 2 weeks and 1, 2, and 3 months after the start of training, and at 1 and 3 months after cessation of training.

Statistical analysis

Data were analyzed using SPSS version 24 software (SPSS Inc., Tokyo, Japan). In Experiment 1, differences in TP and CP at the measurement time point (factor B; before training/1 month/2 months/3 months) for both groups (factor A; control/training groups) with and without gum chewing training were analyzed. In Experiment 2, we analyzed the changes in TP and CP based on sex (factor A; men/women) and duration of gum chewing training (factor B; before training/2 weeks/1 month/2 months/3 months/after cessation). The Shapiro–Wilk test was used to examine normality, and normality was found for all parameters. There was no significance on Mauchly's sphericity

test, so the Greenhouse-Geisser correction was applied. All analyses were performed using repeated two-way analysis of variance and Bonferroni's post-hoc test. Significance was set at $p < 0.05$ or $p < 0.01$, and the power was set to 0.8 for all analyses. Overall, a significant difference was considered to be present when both items were satisfied.

Ethical considerations

All experimental procedures were approved by the Ethics Committee of The Nippon Dental University School of Life Dentistry at Niigata (ECNG-H-154). After explaining the purpose and the methods of the experiment by oral consultation and document, written informed consent was obtained from all subjects.

Results

Experiment 1

Tables 1 and 2 show the Results of repeated two-way ANOVA for differences in TP and CP according to presence or absence of gum chewing training and measurement time point. The main effects of presence and absence of training (factor A; control/training groups) and measurement time point (factor B; before training/1 month/2 months/3 months) on TP and CP were significant. The interaction of both factors was also significant. Based on the results, a simple main effect test was performed prior to multiple comparisons among levels.

Fig. 2 shows the Results of multiple comparison analysis of the change in perioral muscle strength according to presence and absence of gum chewing training and measurement time point. There were no differences in TP and CP between the training and control group before training. It was significantly higher in the training group than in the control group at 1, 2, and 3 months of continuous training. No significant differences were observed between each measurement time point in the control group. On the other hand, TP and CP increased with the progress of continuous training in the training group.

Experiment 2

Tables 3 and 4 show the Results of repeated two-way ANOVA for changes in TP and CP based on sex and duration of training. The main effects of sex difference (factor

Table 1 Results of repeated two-way ANOVA for differences in maximum tongue pressure according to presence or absence of gum chewing training and measurement time point.

Source	SS	df	MS	F value	P value
Presence or absence of training					
A	235.940	1	235.940	5.880	0.023*
Error (A)	882.812	22	40.128		
Measurement time point					
B	443.934	1.511	293.834	50.605	<0.001**
A × B	435.772	1.511	288.432	49.675	<0.001**
Error (B)	192.994	33.238	5.806		

SS: sum of squares. df: degree of freedom. MS: mean square.

**, *: denotes statistical significance (critical region; $P < 0.01$, $P < 0.05$).

Table 2 Results of repeated two-way ANOVA for differences in cheek pressure according to presence or absence of gum chewing training and measurement time point.

Source	SS	df	MS	F value	P value
Presence or absence of training					
A	109.868	1	109.868	5.699	0.026*
Error (A)	424.147	22	19.279		
Measurement time point					
B	57.301	2.377	24.108	26.970	<0.001**
A×B	42.069	2.377	17.699	19.801	<0.001**
Error (B)	46.742	52.291	0.894		

SS: sum of squares. df: degree of freedom. MS: mean square.

**, *: denotes statistical significance (critical region; $P < 0.01$, $P < 0.05$).

A; men/women) and duration of training (factor B; before training/2 weeks/1 month/2 months/3 months/after cessation) on TP and CP were significant, but there was no interaction between these factors.

Tables 5 and 6, and Fig. 3 show the Results of multiple comparison analysis for the change in strength between men and women, and between each point of duration of gum chewing training. Measurements for TP and CP were

significantly higher in men than in women before training. Changes in TP and CP associated with training were similar in men and women, TP and CP were significantly higher in men than in women at all measurement time points. The change in TP between each point of duration of gum chewing training showed significant differences at 2 weeks after starting training in both genders, with increases to about 5.5 kPa (13.1%) in men and 5.5 kPa (16.4%) in women at 2 weeks and about 11.8 kPa (28.2%) in men and about 9.2 kPa (27.3%) in women at 3 months of training. The change in CP between each point of duration of gum chewing training showed significant differences at 1 month after starting training in both genders, with increases to about 1.8 kPa (11.7%) in men and about 1.7 kPa (13.6%) in women at 1 month and about 3.6 kPa (23.2%) in men and about 2.9 kPa (23.0%) in women at 3 months of training. After cessation of training, TP and CP tended to decrease, but there was no significant difference between 3 months after starting training in both genders. TP and CP were also significantly higher than before training.

Discussion

Chewing gum is used in many situations for the improvement dental occlusion, promotion of salivation, dental caries prevention and halitosis prevention. The indications for chewing gum are respectively classified into oral hygiene or improvement of oral function, depending on whether the effect is derived from the ingredients contained in the gum or from the method of gum chewing. Oral functional training with chewing gum focused on the way of chewing were reported, but there are few reports on improving or maintaining the oral function of adults.^{15,18,21} The main purpose of the gum chew training in normal adults are to improve the strength of the tongue and cheek muscles by the continuation of masticatory movement that is equally loaded on the left and right sides. This method of chewing are expected to lead to maintenance of good masticatory function after cessation of training. To accomplish this objective, we devised a program that uses chewing gum to masticate evenly using the left and right molars and with the mouth closed for a set period of time, as unilateral chewing may cause facial distortion. Because this training repeatedly performs simple masticatory movements, we believed that muscle load during training is

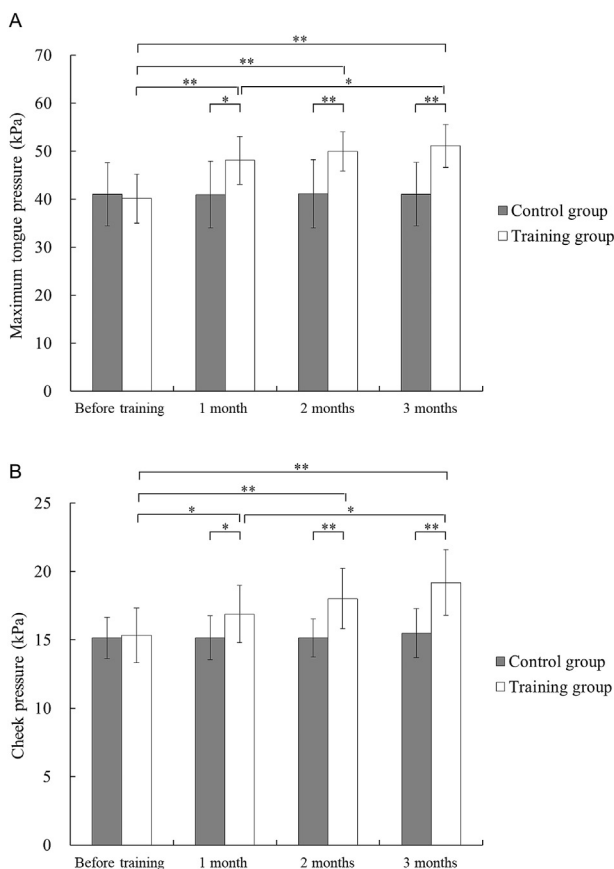


Fig. 2 Results of multiple comparison analysis of the change in perioral muscle strength (mean \pm 1 S.D.) according to presence and absence of gum chewing training and measurement time point. Error bar indicates standard error of the mean. **, *: denotes statistical significance (critical region; $P < 0.01$, $P < 0.05$). A: maximum tongue pressure, B: cheek pressure.

Table 3 Results of repeated two-way ANOVA for change in maximum tongue pressure based on sex and duration of gum chewing training.

Source	SS	df	MS	F value	P value
Sex difference					
A	4548.769	1	4548.769	20.957	<0.001**
Error (A)	6945.700	32	217.053		
Duration of training					
B	2698.314	1.997	1351.193	71.155	<0.001**
A × B	55.907	1.997	27.996	1.474	0.237
Error (B)	1213.494	63.904	18.989		

SS: sum of squares. df: degree of freedom. MS: mean square.

**: denotes statistical significance (critical region; $P < 0.01$).

small and that it would be necessary to continue for a certain period and frequency to expect any efficacy. For these reasons, this training session provided chewing guidance to the subjects, encouraging them to alternately chew in order to equally apply loads to the left and right sides, and it was decided to continue for 5 min each time for 3 months.

Various methods were reported for evaluating the stomatognathic function: that includes saliva secretion, masticatory ability, swallowing ability.^{4,5,11,15,16,18,21–23} In order to perform a normal swallowing and feeding function, the peroral muscles and saliva secretion play a critical role. There have been many reports on using perioral muscle strength, especially tongue pressure (TP), to objectively evaluate the effect of the training of oral function.^{6,9–14} Other evaluations are labial closure strength, upper lip pressure, lower lip pressure and cheek pressure.^{4,6,11,12} The training conducted in this study was chewing exercise that performed mainly in the molars. Because the cooperative movement of the tongue and cheek is performed during chewing, so the effect of training was evaluated by measurement of TP and CP in the present study. However, it would be necessity to consider the upper lip and the lower lip pressure, in the case of perform the oral function training which actively exercises the anterior lip muscle (e.g., button pull exercises or orbicularis muscle training) or when the participants are growth stage.

In the selection of subjects, it is important to note whether the training and control groups belong to the same population. The gender and age of the training and the control groups were therefore kept similar. In Experiment

1, there were no significant differences between the training and control groups in TP and CP before training, suggesting that the two groups belong to the same population. Furthermore, the values of TP and CP at 1, 2, and 3 months after starting training were higher in the training group than in the control group. The standard deviation of the measured values was within a reasonable range when compared to previous research Results^{6,12} using the same measuring instrument (JMS tongue pressure measurement device). Therefore, the increases in TP and CP in the training group were considered to be the result of this training.

In Experiment 2, measurements obtained before training were similar to those previously reported for normal adults aged 20–30 years,^{6,12,14} indicating that the study sample was representative of the general population. Similarly, as in Experiment 1, the standard deviation of the measured values was within a reasonable range when compared to previous research Results^{6,12} using the same measuring instrument. In addition, it has been reported that perioral muscle pressure differs depending on gender,^{6,14} and is related to the muscles mass of the limbs.²⁴ Accordingly, we examined the effects of training separately for men and women in Experiment 2. The results of this study were similar to previous reports,^{6,14} and a sex difference was recognized, with TP and CP in men showing higher values than in women. In this study, the rate of increase in measurement values by training was not different between men and women, and a similar effect appeared regardless of gender. However, it has been reported that the effects of oral functional training depend on subject age and training

Table 4 Results of repeated two-way ANOVA for change in cheek pressure based on sex and duration of gum chewing training.

Source	SS	df	MS	F value	P value
Sex difference					
A	452.823	1	452.823	8.225	<0.01**
Error (A)	1761.781	32	55.056		
Duration of training					
B	225.961	2.251	100.378	25.201	<0.001**
A × B	9.680	2.251	4.300	1.080	0.351
Error (B)	286.922	72.035	3.983		

SS: sum of squares. df: degree of freedom. MS: mean square.

**: denotes statistical significance (critical region; $P < 0.01$).

Table 5 Results of multiple comparison analysis for the change in maximum tongue pressure between each point of duration of gum chewing training. A: men, B: women.

A

	Before training	2 weeks	1 month	2 months	3 months	1 month after cessation	3 months after cessation
Before training							
2 weeks	**						
1 month	**	n.s.					
2 months	**	*	n.s.				
3 months	**	**	**	*			
1 month after cessation	**	**	*	n.s.	n.s.		
3 months after cessation	**	**	*	n.s.	n.s.	n.s.	

**, *: denotes statistical significance (critical region: $P < 0.01$, $P < 0.05$). n.s.: Not Significant.

B

	Before training	2 weeks	1 month	2 months	3 months	1 month after cessation	3 months after cessation
Before training							
2 weeks	**						
1 month	**	n.s.					
2 months	**	*	n.s.				
3 months	**	*	n.s.	n.s.			
1 month after cessation	**	*	n.s.	n.s.	n.s.		
3 months after cessation	**	*	n.s.	n.s.	n.s.	n.s.	

**, *: denotes statistical significance (critical region: $P < 0.01$, $P < 0.05$). n.s.: Not Significant.

methods. In particular, the effects of continuous training in the elderly tend to take a longer time to clarify, because the elderly show a decline in oral function when compared with younger subjects.^{16,25} The standard deviation is also thought to be larger in the elderly than in the healthy population due to the influence of physical and physiological factors. For this reason, the program of gum chewing training needs to be arranged according to factors such as subject age and health. We will therefore need a larger subject pool to determine the effectiveness of training.

In this study, TP and CP tended to be higher at 2 weeks after starting gum chewing training. TP showed a significant difference at 2 weeks for both sexes, and the increase in TP appeared early, similarly to other reports on functional

training for normal adults.⁶ On the other hand, the increase in CP was slower than TP in both sexes and showed a significant difference at 1 month after starting training. This may be due to differences in activity between the tongue muscle and the buccinator during chewing. Both muscles work to keep the gum between upper and lower molars during chewing. In this study, the gum moved from the left molars to the right molars after 10 chews and vice versa. When the gum is moved from one side to the other side, the tongue muscle acts predominantly, and it is more likely to spill on the lingual side during continuous chewing a small food. The burden on the tongue muscle is therefore greater than that on the buccinator during gum chewing. As a result of this study, we demonstrated that continuous gum

Table 6 Results of multiple comparison analysis for the change in cheek pressure between each point of duration of gum chewing training. A: men, B: women.

A		Before training	2 weeks	1 month	2 months	3 months	1 month after cessation	3 months after cessation
	Before training							
	2 weeks	n.s.						
	1 month	*	n.s.					
	2 months	*	*	n.s.				
	3 months	**	**	*	n.s.			
	1 month after cessation	*	n.s.	n.s.	n.s.	n.s.		
	3 months after cessation	*	n.s.	n.s.	n.s.	n.s.	n.s.	

**, *: denotes statistical significance (critical region: $P < 0.01$, $P < 0.05$). n.s.: Not Significant.

B		Before training	2 weeks	1 month	2 months	3 months	1 month after cessation	3 months after cessation
	Before training							
	2 weeks	n.s.						
	1 month	*	n.s.					
	2 months	*	n.s.	n.s.				
	3 months	**	*	*	n.s.			
	1 month after cessation	*	n.s.	n.s.	n.s.	n.s.		
	3 months after cessation	*	n.s.	n.s.	n.s.	n.s.	n.s.	

**, *: denotes statistical significance (critical region: $P < 0.01$, $P < 0.05$). n.s.: Not Significant.

chewing training increases TP and CP. In addition, TP and CP showed no significant differences between 3 months after starting training and cessation of training and maintained a significantly higher value than before training. It was therefore clarified that the effects of gum chewing training are maintained even after cessation of training, that gum chewing training is useful for improving oral function.

The aim of this study was to investigate the usefulness of gum chewing training aimed at improving swallowing and feeding functions. We plan to utilize this training to improve swallowing and feeding functions in the elderly and in patients with swallowing and feeding difficulties. To

that end, it was necessary to first confirm the effects in healthy subjects. In order to perform a normal stomatognathic function, saliva secretion play a critical role. When this training is applied to the elderly and to patients whose swallowing and feeding function has declined, it is predicted that it will predominantly act to increase the amount of saliva secretion and bolus formation. This may lead to improved periodontal pathologies by resulting in changes to oral flora. Furthermore, it may be possible to improve the occlusal force by improving the muscular strength of the masticatory muscles and to stabilize the occlusal balance by equal mastication on the left and right sides. In particular, gum chewing training programs are

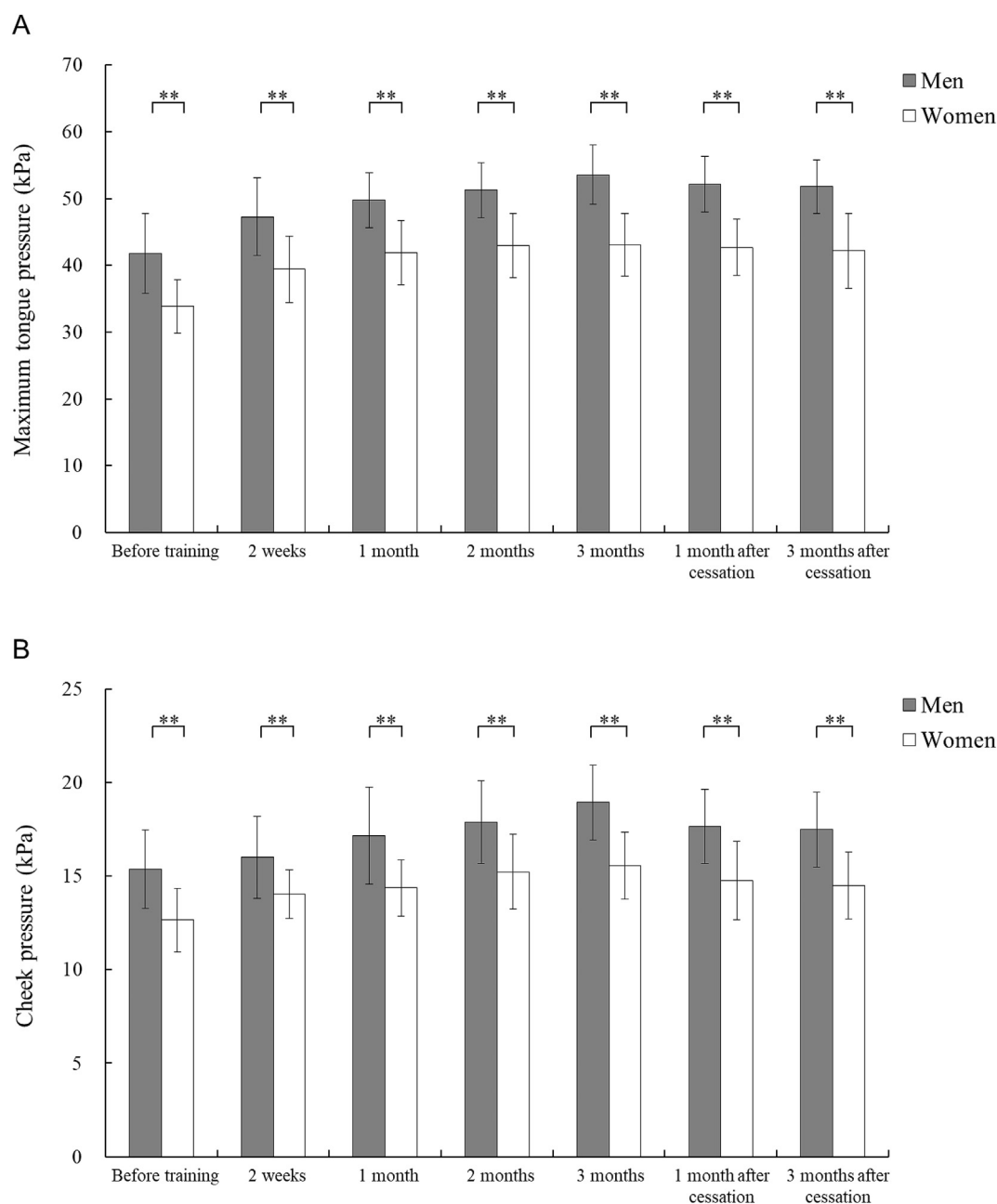


Fig. 3 Results of multiple comparison analysis of the change in perioral muscle strength (mean \pm 1 S.D.) between men and women. Error bar indicates standard error of the mean. **: denotes statistical significance (critical region; $P < 0.01$). A: maximum tongue pressure, B: cheek pressure.

expected to be useful for patients with xerostomia, as training using instruments can cause abrasion of the mucosa and tongue, and continuous training becomes difficult with the accompanying pain. Furthermore, some patients with xerostomia chew gum routinely to increase the saliva secretion; thus, training can be introduced relatively easily by teaching the present chewing method. In the future, it will be necessary to devise a training program that takes into consideration subject background (i.e., age, health status, and denture wearers, etc.), because the effects of continuous training in the elderly tend to take a longer time to manifest.

Conflicts of interest statement

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

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