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An effective salivation-facilitating method for COVID-19 testing

An experimental study

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Abstract

Background: Simple tools, such as antigen test kits, are readily available for determining coronavirus disease 2019 infection at hospitals and homes. However, it is challenging for elderly people who are prone to dry mouth and other diseases. The main objective of this study was to investigate whether the presence or consumption of a plum pickle can facilitate salivation during coronavirus disease 2019 testing.

Method: Twenty healthy adult women participated in the study. The participants were allocated to 2 groups: presentation and non-presentation (n = 10; with and without presentation of a plum pickle, respectively), and eating and non-eating (n = 10; with and without consumption of plum pickle, respectively). We recorded the number of saliva swallows in 1 minute under each condition, using a swallowing test device, which attached film sensors to the hyoid bone and thyroid cartilage.

Results: There was a significant difference in the number of swallows between the non-presentation and presentation groups ($P < .01$, $r = 0.89$, $Z = -2.82$) as well as between the non-eating and eating groups ($P < .01$, $r = 0.85$, $Z = -2.68$).

Conclusions: The strength of 3 factors, namely: direct stimulation with citric acid, saliva buffer capacity, and motor learning, may have affected the results. Our study suggests that saliva collection using the plum pickle is an effective complementary method for facilitating salivation. This technique may be useful in avoiding the risk associated with citric acid intake and for efficient specimen collection during coronavirus disease 2019 testing. In the future, we need to verify this method in elderly participants in a clinical setting.

Abbreviations: COVID-19 = coronavirus disease 2019, PC = personal computer.

Keywords: COVID-19, elderly, salivation, swallow, unconditioned reflex

1. Introduction

Although 3 years have passed since the coronavirus disease 2019 (COVID-19) outbreak occurred in Japan and overseas, there is no prospect of its disappearance. Simple COVID-19-testing tools have become readily available as antigen test kits for determining infection at hospitals and homes. However, it is important to reduce the burden and further facilitate COVID-19 testing. A nasopharyngeal swab or saliva is used as a sample for antigen testing; however, saliva collection is easier at home because it causes less irritation and pain.[1] In order to improve the accuracy of the antigen test, necessary precautions should be taken; for example, neutral saliva (approximately at pH 7) should be collected, and specimen collection must be performed timeously. Thus, it is a difficult task for elderly people who are prone to dry mouth and other diseases.

Here, we focus on the usefulness of plum pickles, referred to as "umeboshi," which are traditional Japanese pickles with red color and sour taste. The intake of acidic foods containing citric acid, such as plums, leads to recovery from fatigue[2] and facilitates salivation.[3] This study aimed to investigate whether the presence or consumption of a plum pickle can facilitate salivation, using a swallowing test device.[4,5] Furthermore, if the presence of plum pickle increases the number of swallows, we can examine the effectiveness in promoting saliva during meals in elderly people with decreased saliva volume. This study may provide knowledge to develop a complementary method for saliva specimen collection during COVID-19 testing.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figure 1. Swallowing test device. The device consists of 3 parts (i.e., a personal computer and 2 film sensors) and an interposer.

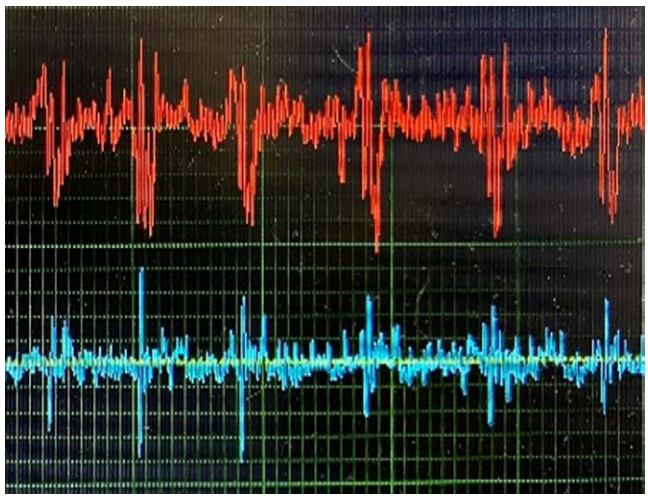

Figure 2. Swallowing reflex waveform. The red waveform (the upper wave) indicates hyoid bone movement, and the blue waveform (the lower wave) indicates thyroid cartilage movement.

2. Methods

2.1. Participants

Twenty healthy adult women participated in the study and were divided into 2 groups: presentation and non-presentation (with and without presentation of a plum pickle, respectively; experiment I; n = 10; mean age 20 ± 9.0 years), and eating and non-eating (with and without consumption of plum pickle, respectively; experiment II; n = 10; mean age 22 ± 1.0 years).

The participants provided informed consent at their workplaces. The study was approved by the Ethics Committee of Nishi Kyushu University (approval no. 22JRV27) and complied with the Declaration of Helsinki.

2.2. Experimental setup

2.2.1. Swallowing test device. The swallowing test device (Science Research Co., Nagasaki, Japan) consisted of a personal computer (PC) with the data collection and analysis program, 2 film sensors to collect swallowing data, a web camera to observe their state during the experiments, and an interposer that connected these 3 parts (Fig. 1). The swallowing reflex waveform and the number of seconds between waveforms were displayed on a PC screen, and the collected data were saved on the PC itself (Fig. 2).

2.2.2. Outcome measures. In experiment I, the number of swallows with and without the visual presence of a plum pickle was collected. In experiment II, the number of swallows with and without plum pickle consumption was recorded. The experimental procedure was counterbalanced, and the participants were asked to perform each action once according to the following procedure: During the experiments, participants were instructed to swallow their saliva as often as possible. In addition, they were asked to refrain from speaking so that the experiments could be accurately performed. The number of saliva swallows in 1 minute under each condition was collected using the swallowing test device, which attached film sensors to the hyoid bone and thyroid cartilage.

2.2.3. Procedures. In experiments I and II, film sensors were attached to the hyoid bone and thyroid cartilage while participants were sitting on a chair (Fig. 3), which was adjusted to the position where the inspection site could be seen. Data were collected using a data acquisition program inserted into a PC. The experimental procedure is illustrated in Figure 4.

2.3. Data and statistical analysis

The number of swallowing reflexes that occurred in 1 minute during experiments I and II were obtained by the data acquisition program, and the waveform data were analyzed using the analysis program. The data were analyzed to compare the conditions in each experiment using the Wilcoxon signed-rank test—a nonparametric test with an almighty property. Considering the number of participants, we selected the method unaffected by outliers. Two-sided probability values of $<.05$ were considered significant. The effect size (r) was calculated from the Z-score of the Wilcoxon signed-rank test[6] to estimate the effect size. All

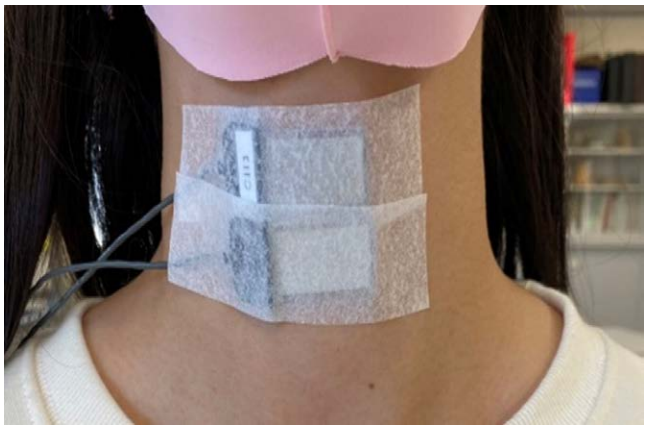

Figure 3. The attached film sensors. For collecting the swallowing data, 1 film sensor is attached to the hyoid bone (upper part), and the other is attached to the thyroid cartilage (lower part).

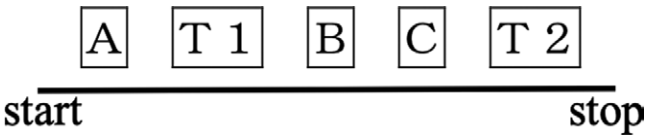

Figure 4. Experimental procedure. Swallowing data were collected at T1 and T2. Data were collected by counterbalancing T1 and T2 and standardizing other procedures and contents. (A) The participants were asked to drink room-temperature water (approximately 10 cc) to standardize dry mouth among the participants. T1: After confirming that the participants drank water, they were asked to swallow saliva for 1 min while looking at the cross point on white paper on the wall 20 cm in front of them. (B) The participants were asked to wash their oral cavity using a wet oral tissue or water. (C) The participants were asked to drink room-temperature water (approximately 10 cc) in order to refresh their mouth's watering. T2: After confirming that the participants drank water, they were asked to swallow saliva for 1 min while looking at a plum pickle placed 15 cm in front of them (in experiment II, participants consumed the plum pickle).

statistical analyses were performed using SPSS Statistics (version 28.; IBM Corp., Armonk, NY).

3. Results

In experiment I, the number of swallows was 4.4 ± 1.15 and 7.2 ± 2.35 without and with the presentation of a plum pickle, respectively; the difference was significant ($P < .01$, $r = 0.89$, $Z = -2.82$), indicating a large effect. In experiment II, the number of swallows was 7.8 ± 3.16 and 11.5 ± 2.33 without and with consumption of a plum pickle, respectively; a significant difference was observed ($P < .01$, $r = 0.85$, $Z = -2.68$), indicating a large effect.

4. Discussion

Significant differences were observed between the non-presentation and presentation and non-eating and eating groups. Moreover, the effect sizes were large in both experiments. The result can be characteristically considered due to the decline in the image of traditional Japanese pickled plums and eating habits among healthy adults. Thus, the result may be affected by subject specificity. The findings suggest that the strengths and weaknesses of the 3 following factors may have affected the number of swallows.

4.1. Stimulation with citric acid

Acidic substances promote swallowing, and salivary secretion increases as the acid concentration increases.[7] This study confirmed that ingesting a plum pickle, an acidic substance, promotes swallowing. This could be caused by a chemical stimulus of citric acid, which is the main component causing sourness, and the volume of saliva secreted increased due to the gustatory sensory input caused by plums.

4.2. Saliva buffer capacity

The pH of the oral cavity during swallowing became acidic due to the plum pickle, and the buffering ability of saliva may have promoted salivary secretion to maintain the pH in the oral cavity. At rest, the pH in the oral cavity is close to neutral.[8] It is considered that the buffering capacity of saliva worked strongly to return the oral cavity to neutrality during swallowing because the plums used in this study exhibited strong acidity with pH 2 to 3. Moreover, buffering capacity increases with increasing liquid outflow.[9] Therefore, salivary secretion is promoted during swallowing because a higher salivary buffering capacity is required during swallowing than during presentation, which is affected only by the conditioned reflexes.

4.3. Motor learning

The stimulation of saliva secretion is possibly affected by motor learning under presentation and eating conditions. These responses are unconditioned reflexes that humans and animals originally have in response to a specific stimulus. The combination of the central stimulus of looking at a plum (the stimulus that does not trigger the unconditioned reflex) and the unconditioned stimulus of eating a plum (the stimulus that triggers the unconditioned reflex) trigger the unconditioned reflex of saliva production. Repeatedly giving an unconditioned stimulus immediately after giving a central stimulus causes an unconditioned reflex only through central stimulation; this process is called classical conditioning.[10] The effect size of the condition of presenting plums was slightly larger than that of the eating condition because the conditioned reflex[11] that was caused by the experience of tasting sourness and its visual memory caused them to feel as if their mouth was sour.

Herein, compared to the conditions of non-presentation and non-eating, presentation and consumption showed a clear effect on the number of swallows. Furthermore, the effect size was large for both presentation and consumption habits. This result reveals that collecting saliva specimens during the visual capture of acidic substances could be effective. Although it has been reported that aspiration of acidic substances can cause severe damage to the lungs and airway mucosa,[12] presenting conditions can lead to risk avoidance and increase saliva volume while adhering to precautionary measures for sample collection during COVID-19 testing. In future research, the effect needs to be verified in clinical practice.

In addition, the large effect size, even in just presenting plum, suggests that it can be used as a preventive method for oral frailty in the elderly in Japan, where the birthrate is declining due to hyper-aging.

This study had several limitations. First, participant selection may have led to bias as all participants were recruited from a single prefecture in Japan. Second, all participants were healthy young adults. Third, the sample size was small. The volume of saliva swallowed due to the presentation of plums might be higher in the elderly than in younger adults due to long-term learning effects. In future research, the generalizability of our findings should be assessed in terms of the actual target of this method with a larger sample size and in other countries.

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Author contributions

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