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Facial Excise Support Equipment for Prevention of Pulmonary Aspiration Using Mouth Pressure Fluctuation

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Abstract. There is a tendency that elderly persons decline in feeding and swallowing. It is well known that the oral training such as a facial exercise has an effect to facilitate a smoothness swallowing motion. This paper describes measurements of face exercises using PET plastic bottle and evaluations based on the electromyography (EMG). Here, the orbicularis oris muscle were focused for an evaluation. As results of APDF analysis, it could be confirmed that the motion of keep exhaling and fast exhaling, and using thin mouthpieces had effects to enhance the activity of the orbicularis oris muscle. Therefore, this paper also describes a training system based on results of analysis.

1. Introduction

Dysphagia is extremely dangerous because it may lead to clogging or coughing without swallowing things well and leading to "aspiration pneumonitis" caused by foreign substance inflow into the respiratory tract. Therefore, in serious patients with swallowing disorder, methods of feeding nutrition directly into the stomach such as nasal nutrition and gastroscopy have been adopted, but this method without accompanying exercise such as mastication only decreases the motor function further It is not possible to feel the enjoyment of living meals. In addition, elderly people suffer from swallowing disorder include decreased oral motor function and decline of salivary function. There are also reports that moving the muscles around the oral cavity by facial exercise or the like and activating the motor function is effective in preventing swallowing disorder [1,2,3]. Therefore, this study aims to develop a training system for prevention and recovery of swallowing disorder by exercising "orbicularis muscle" deeply related to the secretion of the muscle around oral cavity, especially saliva. In this research, we focused on PET bottle exercise as a way to move the orbicularis muscle. PET bottle exercise is training that sucks air in a PET bottle container and then blows it to vary the internal pressure of the container and the internal pressure of the mouth. Because PET bottle is hold with lip only, the orbicularis muscle effectively moves. Here we measure the electromyography (EMG) signal of the orbicularis muscle when changing the internal pressure of the container and consider it together with the variation of the intraoral pressure. In general, training and rehabilitation are effects that can be shown by long-term and ambitious doing. Here, we examined the idea that can continue ambitiously by visualizing the state of training, and constructed a training system based on the results and considerations of the intraoral pressure variation experiment.

2. Air Pressure Measurement of inner mouth

2.1 Measurement System

Fig.1 shows the measurement equipment for air pressure of inner mouth. This equipment is composed of mouthpiece (Diameter: 29mm) and the flexible PET bottle. Air pressure sensor was connected to the side surface of the mouthpiece and output signal was translated to the bridge circuit and amplifier circuit. As shown in Fig.2, the electrodes were put near orbicularis oris muscle and zygomaticus major muscle and zygomaticus minor muscle to measure muscle activity, and ground was attached to a wrist. The electrode unit (Biometrics SX230) of the dry type was used for a measurement. The obtained EMG signal was taken to the personal computer with sampling frequency of 600[Hz].

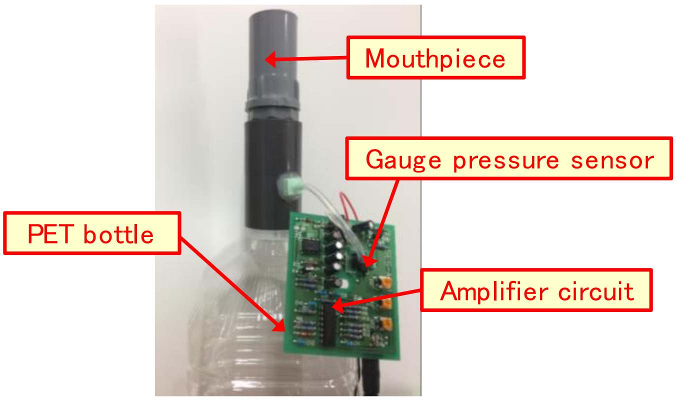


Fig.1 Measurement system for breath pressure

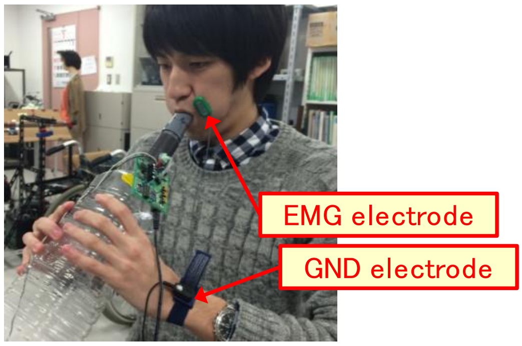
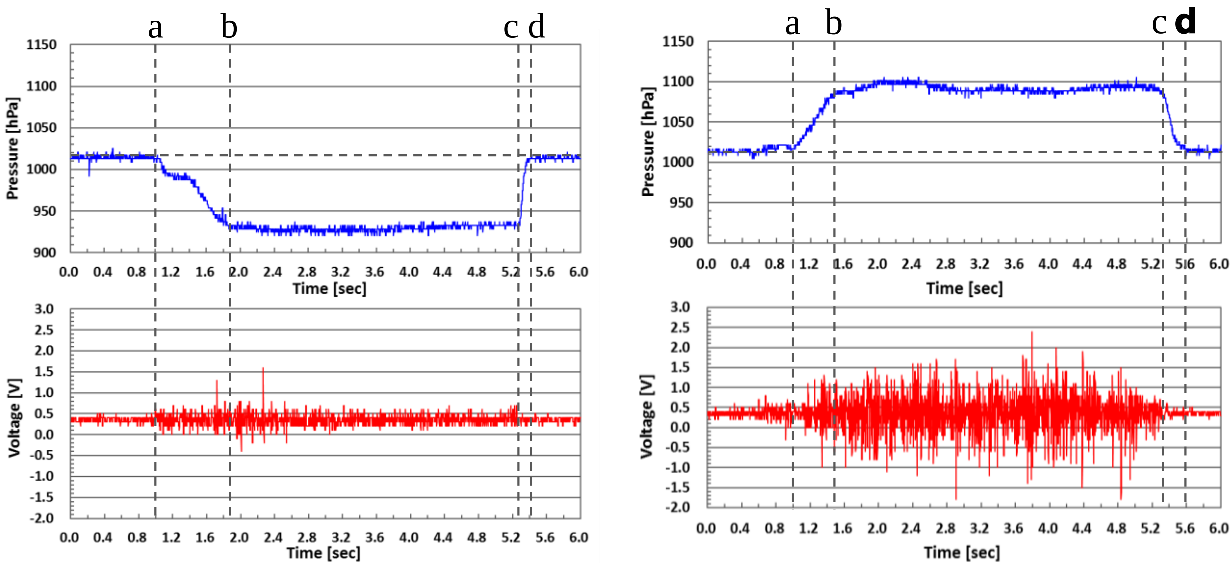


Fig.2 Scene of measurement

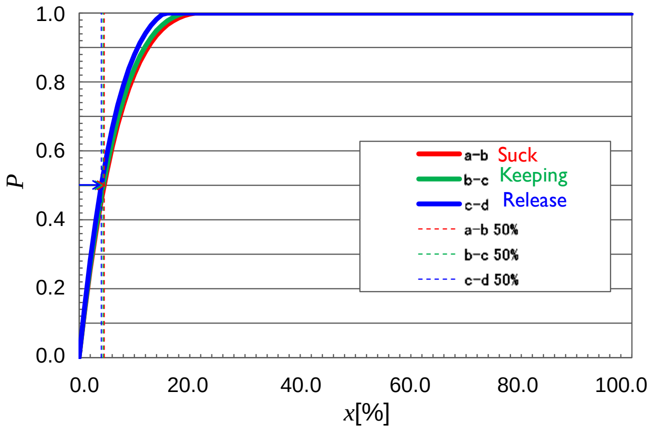


(a) Inhaling (b) Exhaling

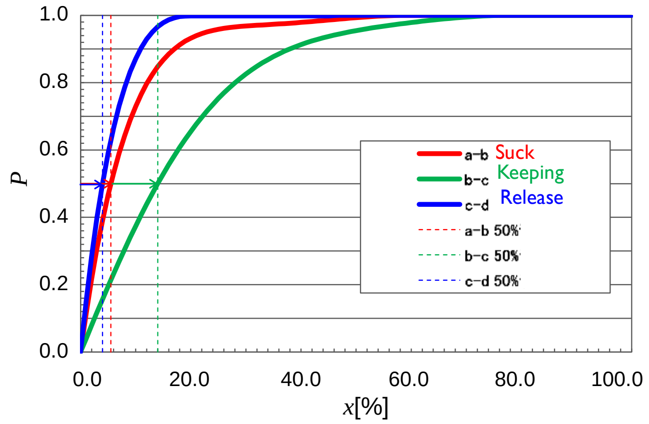
Fig.3 Time series data of inhaling and exhaling

2.2 Blow and Sack Actions

As shown in Fig.2, the mouthpiece was grasped by the lips. Subject kept inhaling air in the PET bottle for 4 seconds and continued to blow for 4 seconds. Typical time series of data is shown in Fig.3. The upper part shows measured waveform of pressure and the lower part shows measured waveform of myopotential signal. In each figure, the point a is the moment when the operation is started, the point b is the moment when the air in the plastic bottle runs out or expands, the point c is the moment when the mouth is released from the mouthpiece, the point d is the moment when the internal pressure returns to the atmospheric pressure. In both Figures, the EMG signal starts to increase from the point a, but it can be confirmed that the case of Fig. 3 (b) continues with a large amplitude, as compared with Fig. 3 (a). From this, it can be said that the blowing motion is more involved in the orbicularis muscle than the sucking motion. Here, the waveform of the signal is divided into three sections shown in the figure, and analysis by the amplitude probability density function (hereinafter referred to as APDF analysis [4] [5]) is performed for each section. The result of APDF analysis is shown in Fig.4. In this study, the maximum relaxation sample value acquired immediately after the measurement was analyzed as MVC. The horizontal axis is the ratio of MCV (x [%]), and the vertical axis is the occurrence probability of values below x [%]. In addition, the load when P = 0.5 is an average load, and the higher the average load value, the more the amplitude of the EMG signal is larger in many cases. That is, muscle activity can be regarded as active. Fig.4 (a) shows the ratio of MCV at P = 0.5 in every section, but Fig.4 (b) holds the blowing motion in the section b-c, that is, with the PET bottle fully inflated. It is understood that muscle activity is growing in the section. The above result said that exercise to maintain the blowing motion is effective for training of the orbicularis muscle. In the next chapter, we constructed a training system to train orbicularis muscles based on the obtained characteristics.



(a) Inhaling



(b) Exhaling

Fig.4 Results of APDF analysis

3. Construction of Training System

3.1 System

The developed training system is shown in Fig.5. This system is composed of a syringe part, a control unit part, and a mouthpiece part. The syringe part is composed of a syringe and a servo motor driven ball screw unit, and an air pressure sensor is attached to a piston inside the syringe. The ball screw unit and the syringe are fixed, and the piston of the syringe moves back and forth as the servomotor is driven. In addition, the initial value of the pressure sensor is based on the atmospheric pressure, and when the exhalation pressure exceeds the threshold value of pressure set by using the PC, the specification is such that the servomotor is driven in the direction of pulling the piston. A proximity sensor is attached to the piston, and a change in the output value is used for detecting the piston position. The output values of the pressure sensor and the proximity sensor were taken into the PC via the microcomputer Arduino, and the speed of the motor was controlled by changing the duty ratio of the servomotor. By the user performing the blowing operation through the mouthpiece, the pressure inside the syringe increases and the servo motor starts to drive. The moment the piston moves to the end point position, the user releases the mouth from the mouthpiece, and at the same time the servo motor starts to return to the initial position. When the expiration pressure falls below the threshold value, the drive of the servo motor is stopped.

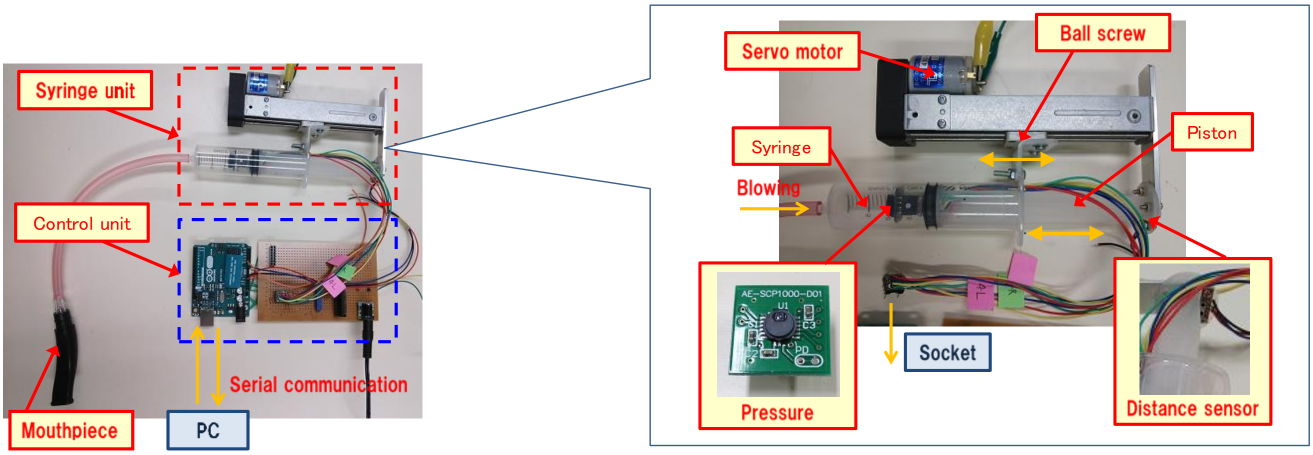
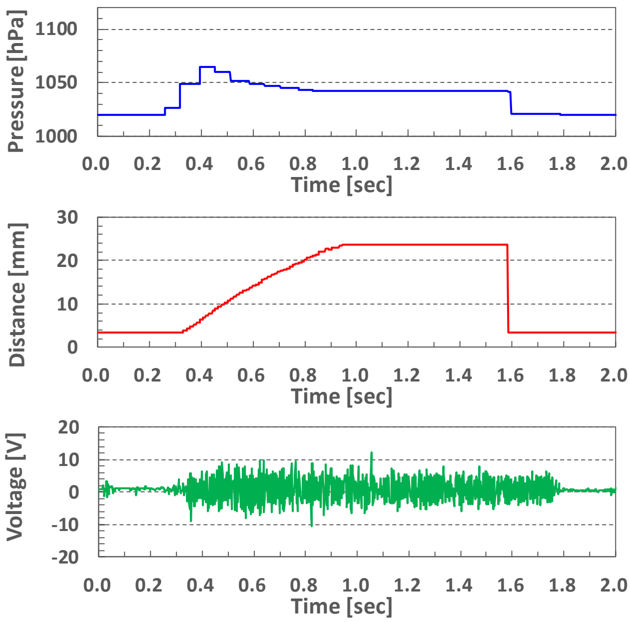


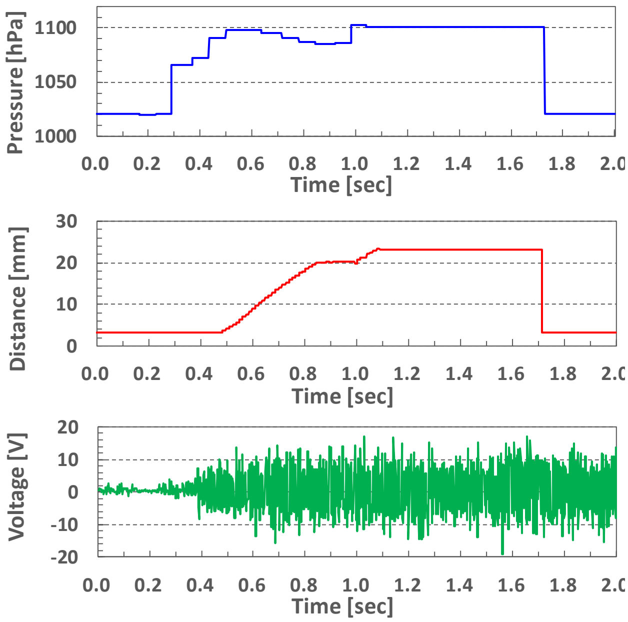
Fig.5 Training system

3.2 Verification Experiment

The effect of the training system was verified by examining the amount of activity of the orbicularis muscle when using the constructed training system. In this experiment, we evaluated the relation between the training effect, the pressure suitable for training and the optimal speed of the servomotor



(a) Threshold is +1[hPa]



(b) Threshold is +65[hPa]

Fig.6 Time series data of training

by changing the threshold value of the pressure sensor and the duty ratio of the servomotor. Typical measurement waveform is shown in Fig6. The upper part shows the measurement waveform of the pressure, the middle part shows the output waveform of the proximity sensor, and the lower part shows the measurement waveform of the myoelectric potential signal. Comparing the amplitudes of the measured waveforms, it can be confirmed that a large amplitude appears in the measured waveform when the threshold value of the pressure sensor is set to +65.00 [hPa]. It is thought that this was due to the action of keeping blowing in at a pressure higher than that as a result of setting the pressure threshold high. On the other hand, in experiments where the threshold value of the pressure sensor was set at +1.00 [hPa], it was possible to perform the blowing operation with a very small load. However, a slight amplitude was observed in the waveform of the myoelectric potential signal. Therefore, it can be said that the blowing operation can lead to training even with a very small load.

4. Conclusions

In this study, we focused on changes in intraoral pressure and developed a training system to promote secretion of saliva by forging the orbicularis muscle. First, we constructed a device to measure intraoral pressure and EMG signals of the orbicularis muscle, and conducted an experiment to measure the EMG of the orbicularis muscle when sucking action and blowing action were performed. We also examined exercise that can efficiently train the orbicularis muscle. As a result, it was found that the muscle activity of the orbicularis muscle increased by exercising to maintain the blowing motion. Based on the obtained results, we focused on maintaining the action of blowing air and constructed a training system to train the orbicularis muscle. In the training system, air is blown into the device to drive the servomotor by increasing the intraoral pressure, thereby keeping the blowing operation while giving a certain load to the user. As a result of experiments to verify the effectiveness of the constructed training system, it is possible to obtain a high muscle activity amount by performing the blowing operation at a high pressure, but on the other hand, the blowing action at a low pressure also leads to training. From the obtained result, it can be said that more effective training can be carried out by carrying out training with a load suitable for the user's age and body condition.

Acknowledgements

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