Respiratory pattern on mastication and swallowing

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This experiment was conducted to measure respiratory arrest and resumption on mastication and swallowing, analyze respiratory patterns, and clarify respiratory kinetics. The subjects were 8 adult males. The nasal respiratory kinetics were measured using a differential pressure pneumotachograph, with the flow rate used as a parameter. Laryngeal movement was measured using an acceleration pick-up. Cooked rice (12 g or 24 g) was used as the test food. Test movements consisted of free mastication and swallowing. For this experiment, the subjects were placed in a vertical sitting position. The respiratory kinetics and laryngeal movement waveforms were simultaneously recorded using a data recorder, and analyzed. We found that the respiratory pattern on mastication and swallowing was expiration-swallowing-expiration in 81.2% of the subjects. There was no significant difference in the respiratory pattern on mastication and swallowing between the two swallowing volumes (12 g and 24 g). There was also no significant difference in the respiratory pattern between insertion and terminal swallowing. The results of this experiment showed that the respiratory pattern on swallowing differed between interposed and masticatory swallowing. The results also suggest that, even on masticatory swallowing, different foods influence the respiratory pattern. (J Osaka Dent Univ 2013; 47: 221–225)

Key words: Respiration; Mastication; Swallowing

INTRODUCTION

Currently, the mode of swallowing is classified into 4 types: interposed, masticatory, pharyngeal, and serial swallowing.1 With respect to respiratory kinetics on swallowing, the respiratory pattern, apnea time, and respiratory arrest on interposed swallowing have been reported.2 3 However, the mode of swallowing during meals is masticatory swallowing, and is explained using a process model.4 Concerning the respiratory kinetics on masticatory swallowing, although several studies have reported the respiratory pattern and respiratory arrest,5 6 the data vary among different conditions and environments during the measurement of respiration.5 7 The respiratory kinetics on masticatory swallowing remain to be clarified. In this experiment, we analyzed the respiratory pattern to clarify the respiratory kinetics on masticatory swallowing.

MATERIALS AND METHODS

Subjects
The subject were 8 males without subjective or objective abnormalities in swallowing or respiratory functions between 23 and 29 years of age, with a mean of 26 years. Prior to the experiment, its methods and significance were explained to the subjects. Informed consent regarding participation in this experiment was obtained according to the Helsinki Declaration (Ethics Review Board of Osaka Dental University, No.100507).

Measurement system of nasal respiratory kinetics
The nasal respiratory kinetics were measured using a Pneumotach System (RSS100HR; Hansrudolph, Shawnee, KA, USA). The nasal region was covered with a nasal mask (RSS100HR; Hansrudolph). After confirming the absence of air leakage, the sensor flow
range was established as 0 to 160 L/min, and the nasal respiratory flow rate was measured.

**Measurement system of laryngeal movement**
Laryngeal movement was measured as a parameter of swallowing motion. For measurement, PV-90B acceleration pick-up (RION, Tokyo, Japan) was applied on the skin of the anterior excavation area of the laryngeal thyroid cartilage using surgical tape. Simultaneously, the acceleration pick-up was fixed to a resin plate of 1.5 cm × 1 cm as described by Ohara. The waveforms obtained were amplified at a sensitivity of 0.48 mv/DIV using the PV-90B charge amplifier.

**Block diagram**
A block diagram of the experiment shown in Fig. 1. The waveforms of respiratory kinetics and laryngeal movement were simultaneously recorded and analyzed using a data recorder (SIR-1000i; Sony, Tokyo, Japan), input to a personal computer.

**Experimental method**
Cooked rice was used as the test food. The portions were 12 g (a mouthful) and 24 g (a 2-fold amount). When the latter was placed in the mouth, it comprised the greater portion of the oral capacity at rest in most subjects. Free masticatory swallowing was investigated as a test motion. For this experiment, the subjects were placed in a vertical sitting position, and instructed to eat as usual. They were told to signal when the oral cavity became empty. This represented the completion of one session. Three sessions were randomly conducted. We confirmed that there was no choking or nausea during or after the experiment, and that respiration was stable during the measurements.

**Insertion and terminal swallowing**
In this experiment, the last swallowing point in each session was regarded as terminal swallowing, and swallowing prior to terminal swallowing as insertion swallowing.

**Nasal respiratory kinetics on masticatory swallowing**
A representative respiratory locus and laryngeal movement waveform on mastication and swallowing of rice are presented in Fig. 2. The respiratory pattern of expiration and inhalation on swallowing was classified into 4 categories based on respiratory waveforms before and after swallowing according to a conventional classification: expiration-swallowing-expiration, inhalation-swallowing-expiration, expiration-swallowing-inhalation, and inhalation-swallowing-inhalation...

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Fig. 1 Block diagram of experiment.

Fig. 2 Respiratory locus and laryngeal movement waveform on rice mastication and swallowing. In a Pneumotach System, air current passing through a sensor is directly measured. A respiratory waveform curve above the base line represents an expiratory flow rate, while that below the base line represents the inspired air flow rate. When air current is absent, the respiratory waveform is consistent with the base line. On swallowing, respiration transiently stops, which is consistent with the peak of laryngeal movement, and the waveform becomes flat on the base line, suggesting apnea on swallowing.

Sw: Swallowing, Ex: Expiration, In: Inspiration, AS: Duration of apnea on swallowing.

Fig. 3 Classification of respiratory patterns on swallowing.
tion (Fig. 3).

RESULTS

Respiratory pattern
The data regarding the respiratory patterns on mastication and swallowing are shown in Fig. 4. The pattern was evaluated as expiration-swallowing-expiration in 81.2% of the subjects, inhalation-swallowing-expiration in 7.1%, expiration-swallowing-inhalation in 8.4%, and inhalation-swallowing-inhalation in 3.2%.

Swallowing volume and respiratory pattern
The data for the respiratory pattern on swallowing 12 g and 24 g of cooked rice are shown in Fig. 5. The respiratory pattern for 12 g was expiration-swallowing-expiration in 79.7% of the subjects, inhalation-swallowing-expiration in 8.5%, expiration-swallowing-inhalation in 6.8%, and inhalation-swallowing-inhalation in 5.1%. The respiratory pattern for 24 g was expiration-swallowing-expiration in 82.1% of the subjects, inhalation-swallowing-expiration in 6.3%, expiration-swallowing-inhalation in 9.5%, and inhalation-swallowing-inhalation in 2.1%. Although the percentage of subjects with the expiration-swallowing-expiration pattern was 2.4% higher for 24 g, there were no significant differences in the respiratory patterns between 12 g and 24 g.

Respiratory pattern on insertion and terminal swallowing
Data on the respiratory patterns for insertion and terminal swallowing are shown in Fig. 6. The respiratory pattern on insertion swallowing was evaluated as expiration-swallowing-expiration in 79.6% of the subjects, inhalation-swallowing-expiration in 8.3%, expiration-swallowing-inhalation in 8.3%, and inhalation-swallowing-inhalation in 3.7%. The respiratory pattern on terminal swallowing was evaluated as expiration-swallowing-expiration in 84.4% of the subjects, inhalation-swallowing-expiration in 4.4%, expiration-swallowing-inhalation in 8.9%, and inhalation-swallowing-inhalation in 2.2%. Although the percentage of subjects with the expiration-swallowing-expiration pattern on terminal swallowing was 4.8% higher than on insertion swallowing, there were no significant differences in the respiratory pattern between the two.

DISCUSSION

Respiratory pattern on mastication and swallowing
Umezaki reported that during interposed swallowing of 5 mL of water, 66.9%, 20.3%, and 12.8% of healthy adults showed the respiratory patterns of expiration-swallowing-expiration, inhalation-swallowing-expiration, and expiration-swallowing-inhalation, respec-
tively. No subject showed the inhalation-swallowing-inhalation pattern. Matsuo\textsuperscript{5} indicated that the ex-
piration-swallowing-expiration pattern was observed in approximately 67% to 79% on interposed swallow-
ing. In addition, Kamakura\textsuperscript{2} reported that 60.5% of young subjects showed the expiration-swallowing-
inhalation pattern on interposed swallowing. How-
ever, he used a sub-classification different from the respiratory pattern classifications we used in this ex-
periment. In this experiment, we found the respiratory pattern on mastication and swallowing of expiration-
swallowing-expiration in 81.2% of the subjects. This percentage was higher than that on interposed swallow-
ing previously reported.

Furthermore, we examined the influence of the water volume on the respiratory pattern during inter-
posed swallowing. There was no influence of the swallowing volume on the respiratory pattern in this experiment involving mastication and swallowing, although the respiratory pattern did depend on the water volume according to another study.\textsuperscript{2} This was possibly because the expiratory phase appeared be-
fore swallowing in an increased number of subjects on mastication and swallowing, as food mass transport (stage II transport) to the pharynx during mastication may occur at the time of expiration.\textsuperscript{12}

In addition, another experiment with rabbits showed that the duration of the expiratory phase was short-
ened through periodontal ligament input on mastication,\textsuperscript{13} and that the centers of mastication and swallow-
ing and respiration influenced one another.\textsuperscript{14} Based on these findings, coordination between respi-
ration and swallowing timings may have been intensi-
fied in the center to minimize the risk of aspiration in response to a mastication-related reduction in the ex-
piratory phase, increasing the percentage of subjects with the expiration-swallowing-expiration pattern on mastication and swallowing in this experiment. These results showed that the respiratory pattern differed between interposed and masticatory swallowing.

Swallowing on mastication is classified into 2 types: insertion swallowing during ingestion and ter-
ninal swallowing to transport the last food mass. Al-
though there is no difference in lingual bone move-
ment between insertion and terminal swallowing,
REFERENCES