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Effect of body posture on involuntary swallow in healthy volunteers

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HIGHLIGHTS

- Swallowing was recorded during pharyngeal water infusion/chewing at four postures.
- Reclining changed the location of bolus head at start of swallow.
- Muscle burst duration and whiteout time significantly increased with reclining.
- Body reclining may prolong pharyngeal swallow during involuntary swallow.

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ABSTRACT

Clinically, reclining posture has been reported to reduce risk of aspiration. However, during involuntary swallow in reclining posture, changes in orofacial and pharyngeal movement before and during pharyngeal swallow should be considered. Further, the mechanisms underlying the effect of body posture on involuntary swallow remain unclear. The aim of the present study was to determine the effect of body posture on activity patterns of the suprahyoid muscles and on patterns of bolus transport during a natural involuntary swallow. Thirteen healthy male adults participated in a water infusion test and a chewing test. In the water infusion test, thickened water was delivered into the pharynx at a very slow rate until the first involuntary swallow was evoked. In the chewing test, subjects were asked to eat 10 g of gruel rice. In both tests, the recording was performed at four body postures between upright and supine positions. Results showed that reclining changed the location of the bolus head at the start of swallow and prolonged onset latency of the swallowing initiation. Muscle burst duration and whiteout time measured by videoendoscopy significantly increased with body reclining and prolongation of the falling time. In the chewing test, reclining changed the location of the bolus head at the start of swallow, and the frequency of bolus residue after the first swallow increased. Duration and area of EMG burst and whiteout time significantly increased with body reclining. These data suggest that body reclining may result in prolongation of pharyngeal swallow during involuntary swallow.

1. Introduction

Swallowing, an early stage of the eating process, involves complex sensorimotor neural components. The basic motor patterns involved in swallowing are programmed by the central pattern generator (CPG) in the medulla oblongata [1,2]. Because the swallowing CPG receives both peripheral and central inputs, such inputs determine the threshold for initiation of swallow and the activity pattern of swallow-related muscles [1,3].

Numerous studies have shown that sensory inputs arising from a food bolus affect the patterns of swallowing movement [4–13]. Most studies have focused on the effect of bolus properties such as hardness, adhesiveness, cohesiveness, or viscosity on voluntary swallowing parameters. Voluntary swallowing can be triggered by convergence of central and peripheral inputs into the swallowing CPG, while involuntary swallowing can be triggered by mechanical or chemical stimulation in the oropharynx or larynx. As such, during involuntary swallowing the brainstem neural network may be a dominant component for initiation and determination of movement patterns, although cortical and/or subcortical regions are also involved in involuntary swallowing [14–16].

There is also evidence that body posture may influence swallowing performance, including bolus transport and muscle activity during swallowing [6–8,17–21]. Lund et al. [22] demonstrated that digastric electromyographic (EMG) activity was larger in the upright position than in the supine position. Inagaki et al. [6,18] showed that lying

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down shortened the EMG burst duration of suprahyoid muscles, which was due to the properties of the bolus, as the toughness and adhesiveness of the food could alter the gravitational force in the oral cavity. Moller et al. [20] also evaluated effect of body posture on saliva swallowing, and found that in reclined and supine positions, onset of lateral pterygoid and digastric muscle bursts were advanced in relation to the temporal muscle when compared with the upright position, which may result in shortening of the oral phase of swallowing. Further, Johnsson et al. [19] demonstrated that hypopharyngeal pressure and diameter of the maximal opening of the upper esophageal sphincter (UES) during pharyngeal swallow increased, and the duration of UES opening was shorter in a supine position compared with an upright position. By contrast, Dejaeger et al. reported that the amplitude, duration, and propagation velocity of pharyngeal contraction were not affected by body posture [17]. Most studies that have evaluated EMG activity of the suprahyoid muscle group or in healthy subjects showed no difference in muscle activity during swallowing among various postures [6,20,21]. In addition, Barkmeier et al. [23] reported that the timing, amplitude, and duration of the thyroartenoid muscle did not vary relative to the suprahyoid muscles in healthy subjects. Thus, differences in bolus conditions may have contributed to these contrasting findings.

Clinically, reclining posture was reported to reduce risk of aspiration when compared with an upright or supine posture in dysphagic patients [24–26]. In this posture, the bolus is likely propelled through the posterior wall of pharynx into the upper esophageal sphincter, but not into the larynx. Park et al. [25] found that a 45° reclining position reduced the rate of penetration/aspiration and decreased the residue in valleculae, but increased the residue in the pyriform sinuses, in dysphagic patients. Umeda et al. [26] also reported that reclining position posture can aid oral transit and readily prevent aspiration and laryngeal penetration; in patients with post operation of oral tumors, laryngeal penetration and aspiration were less likely to occur in the reclining position, while the mean oral transit time of the bolus was significantly shorter than when sitting. However, changes in body posture may affect other functions such as respiration [25,27]. Indeed, Park et al. [25] found that the residue in the pyriform sinuses was significantly increased when at a 45° reclining position versus at an upright position.

Although previous studies have examined the effect of body posture on voluntary swallowing, the underlying mechanisms for involuntary swallow remain unclear. Most normal swallowing, such as saliva swallowing and swallowing following chewing during a meal, is initiated involuntarily. The position of the leading edge of the bolus may be different between normal and volitional swallowing following chewing [28]. In particular, during involuntary swallow in the reclining position, there may be a reduction of involvement of orofacial movement before pharyngeal swallow, a decrease in the speed of bolus transport, and an increase of pharyngeal transit time due to changes in the angle of the pharyngeal walls with respect to the perpendicular direction. Further, if the bolus is propelled on the posterior wall of the pharynx before swallowing, the time of initiation of swallowing may be delayed because the posterior wall of the pharynx is poorly innervated [29,30].

Assuming that gravitational effects on oral and pharyngeal bolus transport differ among the postures, a bolus could be predicted to move more slowly in the posterior wall of the pharynx in the reclined position than in the upright position. As a result, a pharyngeal transit time and swallow-related EMG could be larger in the reclined position. Thus, the aim of the present study was to determine the effect of body posture on (1) activity patterns of the suprahyoid muscles and (2) patterns of bolus transport in the pharynx during involuntary saliva swallowing and swallowing following chewing, and (3) to evaluate the relationship of modulation between muscle activity and bolus transport in natural swallow.

2. Materials and methods

2.1. Participants

Thirteen healthy male adults (mean age ± SD: 29.8 ± 6.0 years; age range: 21–39 years) participated in this study. We did not recruited female participants because anatomical and functional differences between men and women have been described in numerous studies [31–35]. Informed consent was obtained from all participants, and no subject had a history of alimentary disease, pulmonary disease, neurological disease, musculoskeletal disorders, speech disorders, voice problems, or masticating or swallowing problems. The experiments were approved by the Ethics Committee of the Faculty of Dentistry, Niigata University (27-R3-5-25).

2.2. Physiological recordings

To identify and evaluate swallowing function, EMG, electroglottography (EGG), and respiratory airflow were recorded, as previously reported [36]. In brief, bipolar surface EMG electrodes (ZB-150H; Nihon Kohden, Tokyo, Japan) were attached to the skin over the anterior surface of the digastric muscle on the left side, and EMG signals were detected in the suprahyoid muscle group. Signals were filtered and amplified (low cut, 30 Hz and high cut, 2 KHz) (WEB-1000; Nihon Kohden) to remove movement-related artifacts. Bipolar surface EGG electrodes were positioned on both the right and left sides of the thyroid cartilage and the signals were amplified (EGG-D200; Laryngograph, London, UK). For recording expiratory and inspiratory airflow via thermocouples, thermal electrodes (ZB-153H; Nihon Kohden) were attached just below the external nostril on either side. The signal was filtered and amplified (high cut, 100 Hz). Flexible endoscopy was performed to observe bolus transport in the mid and hypo-pharynx. A fiber optic endoscope (FNL-10RP3; Pentax, Tokyo, Japan) was inserted through the nasal passage and into the midpharynx. All signals were stored through an interface board (PowerLab; ADInstruments, Colorado Springs, CO, USA) on a personal computer. The sampling rate was 10 kHz for all physiological variables and 30 Hz for VE images. Data analysis was performed using the PowerLab software package (LabChart6; ADInstruments).

2.3. Data collection

Prior to each experiment, the subject was not allowed to eat and drink for at least 1 h. Individual subjects were instructed to lie comfortably on the chair with a head support. We performed two recording sessions involving a water infusion test and a chewing test, which were performed on separate days with an interval of at least two days.

For the water infusion test, thickened water (Oishi-mizu; Asahi Soft Drinks, Ibaraki, Japan) was prepared at 1% thickening agent (Toromi Up Perfect; The Nissin Oilio Group, Ltd., Tokyo, Japan). Following setup of the recording device, a thin tube (2.7 mm outer diameter; NIPRO, Osaka, Japan) was inserted into the posterior tongue transorally. The tip of the tube was positioned at the vallate papilla. The portion of the tube outside the mouth was taped below the lower lip. Prior to experimentation, the subject was asked to swallow his own saliva for a few seconds before recording to clear the saliva in the oral and/or pharyngeal cavity. The liquid was then delivered through the tube using an infusion pump (KDS-100; Muromachi, Tokyo, Japan). The start of infusion was determined at the end of the expiratory phase. To minimize the mechanical effect of the infused solution, it was infused at a very slow rate (0.05 mL/s) until the first involuntary swallow was evoked. The subjects were blinded to the start of water infusion.

For the chewing test, a 10 g portion of gruel rice (Eiyo Shien Okayu; Foricafoods Corp., Niigata, Japan) was prepared. As with the water infusion test, the subject was asked to swallow his own saliva for a few seconds before recording. The food samples were placed on a dish in front