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Effects of olfactory and gustatory stimuli on the biomechanics of swallowing

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ABSTRACT

We have previously documented increased amplitude of motor-evoked potentials (MEPs) from the submental muscles during volitional swallowing following simultaneous odor and tastant stimulation. The MEP denotes neural excitability from the motor cortex to the target muscle(s). However, it is unknown if changes in the MEP transfer to the swallowing muscles to facilitate improved swallowing. Thus, we sought to evaluate changes in the biomechanics of swallowing following stimulation protocols that are known to influence neural excitability. Sixteen healthy participants were exposed to low and high concentrations of lemon odor and tastant. The odor and tastant concentrations which produced the highest amplitude of submental electromyography (EMG) were then combined for simultaneous stimuli presentation. Outcome measures included EMG from the submental muscles, as well as lingual and pharyngeal manometry. Poststimulation results showed decreased midglossopalatal pressure at 30 min and decreased duration at anterior and midglossopalatal pressure and increased EMG duration at 60 min. This study strengthens the justification for the use of flavor in managing patients with dysphagia as long-term changes were present in the poststimulation period.

1. Introduction

Combined olfactory and gustatory stimulation (flavor) has been shown to increase neural excitability in healthy participants, as measured by the amplitude and latency of motor-evoked potentials (MEPs) recorded from the submental muscles [1]. Increased MEP amplitude has been associated with neuroplastic changes in the unaffected hemisphere of nondysphagic poststroke patients compared to patients with dysphagia following stroke who showed no changes in their unaffected hemisphere [2,3]. Although we have reported increased MEP amplitude following simultaneous odor and tastant stimulation, changes in neural excitability do not directly imply functional changes in swallowing. Similarly, an absence of change in neural excitability would not necessarily suggest an absence of functional change in swallowing.

Submental muscles, comprised of the anterior belly of digastric, mylohyoid, and geniohyoid muscles, are involved in the superior and anterior excursion of the hyolaryngeal complex, which is an important biomechanical event to facilitate opening of the upper esophageal sphincter (UES) for bolus transfer [4]. Surface electromyography (sEMG) of the submental muscles is a noninvasive method to study swallowing function [5–7]. Although normal swallowing function is highly variable across individuals, EMG can be used to compare within-subject swallows [6]. Several studies have evaluated EMG of the submental muscles following sour taste stimulation. The submental muscles were found to contract earlier when sour taste was used, compared to a no-taste condition [8]. Contractions of the submental muscles were stronger and the onsets were closer across the three muscles when sour bolus was presented compared to a control condition [9]. EMG recordings of submental muscle contraction were greatest when recorded during swallowing of sour taste, compared to sweet, salty, or bitter [10]. When mechanical, cold, and/or sour stimulation was presented to the anterior faucial pillars, there was a shorter latency in the first swallowing activity when all three conditions were combined, compared to no stimulation, but no changes in the duration of submental contraction were detected [11]. Conversely, another study identified no differences in submental EMG recordings when either high or low concentration of sour food was ingested [12].

Prior to swallowing, the tongue generates pressure which propels a bolus into the pharynx by squeezing the tongue to the palate in an anterior to posterior movement [13]. The pattern of pressure generation in the oral cavity has been systematically studied using pressure transducers secured in a base plate, similar to a denture, which a volunteer wears [14,15]. This method guarantees that the transducers are in situ at all times, ensuring the reliability and stability of the recorded pressures; however, it requires custom-fitted

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hardware. Measures of pressure data in healthy participants, as well as in patients with head and neck cancers, have also been reported to be reliable and stable when using a commercially available lingual pressure bulb (Kay® Digital Swallowing Workstation, Kay Elemetrics Corporation, Lincoln Park, New Jersey, USA) [16,17]. The normal swallowing pattern in healthy individuals was not altered with the presence of the lingual bulb in the mouth [18]. Using this system, lingual pressure was increased when 10-ml chilled sour boli were presented compared to water [19]. It is possible that retronasal odors may have also contributed to the higher lingual pressures seen in that study. Furthermore, bolus volume or temperature, or both, may have contributed to the increased pressure.

The pharynx contracts in a superior to inferior direction to transfer the bolus into the esophagus [20]. Adequate pharyngeal pressure during swallowing clears the pharynx of residue [21]. If inadequate pressure is generated, postswallow residue in the pharynx can enter the airway when the airway re-opens to resume breathing [22,23]; therefore, measurement of pharyngeal pressure provides a valuable indicator of successful swallowing. Pharyngeal pressure can be measured by solid state manometry [20]. Many studies have looked at pharyngeal pressure following other behavioral interventions [24–29] but no study has evaluated the immediate effects of odor or taste on pharyngeal pressure during swallowing. Moreover, to our knowledge, no poststimulation data exists to document the effects of sensory stimulation on the biomechanics of swallowing over a long time course.

The current study is a follow-up to our MEP research which has shown increased MEP amplitude during swallowing following simultaneous odor and tastant stimulation, indicating that the neural substrates involved in swallowing are modulated following sensory intervention. The current study aimed to determine if the same stimulation would change biomechanical swallowing function by way of changes in the contraction of the submental muscles, the pressures in the oral cavity and pharynx, and/or the dynamics of the UES. We hypothesized that there would be an increase in the amplitude of submental surface EMG, lingual and pharyngeal pressures, and the negative pressure in the UES when flavor is presented compared to no stimulation.

2. Methods

A repeated-measures within-subject study design was used to evaluate changes in the biomechanical aspects of swallowing. Ethical approval was obtained from the regional Health and Disability Ethics Committee.

2.1. Participants

Sixteen healthy participants aged 19–47 years (mean 27.5, SD 7.8) were recruited. They reported no previous history of neurological problems or dysphagia and were not taking medication that could affect swallowing. They were all asked not to ingest caffeine, alcohol, or spicy food during the hour prior to the procedures to ensure our stimuli were not contaminated by chemical residues of food in the mouth.

2.2. Stimuli

Low (25%) and high (100%) concentrations of lemon concentrate (Country Gold lemon juice, Steric Trading Pty Ltd, Villawood, NSW, Australia) were utilized in this study. Tap water was used as control. The odor was presented as a mist via nasal cannula attached to a nebuliser (DeVilbiss PulmoMate® compressor/nebuliser, Model 4650I, Sunrise Medical, Somerset, Pennsylvania, USA) and taste was presented by placing filter paper strip (Genuine Whatman Filter Paper No. 5, W & R Balston, Maidstone, Kent, UK) impregnated with the stimulus on the tongue.

2.3. Procedures

Participants provided written informed consent prior to the procedures. Additionally, they were also asked to complete a brief medical questionnaire to confirm that they met the inclusion and exclusion criteria to participate in the study. Prior to data collection, the tongue array and pharyngeal manometer were calibrated following the manufacturer's recommendation.

The participants were seated comfortably in a chair and the surface under the chin was cleaned vigorously with an alcohol swab. A triode surface electrode 5.4 cm in diameter (disposable pregelled electrode pads, standard silver/silver chloride EMG electrodes, Multi Bio Sensors, El Paso, Texas, USA) was placed under the chin, between the spine of the mandible and the superior border of the thyroid cartilage. The two active electrodes were positioned in the midsagittal plane and the ground electrode was positioned laterally. The differential EMG signal of the submental muscles was amplified, band-pass filtered (50–220 Hz), rectified, low-pass filtered at 3 Hz, and digitized at 1000 Hz. The EMG recording system is part of the Kay® Digital Swallowing Workstation. The averaged and rectified EMG waveforms were checked to ensure that clear EMG recordings were achieved.

Next, the manometer was inserted transnasally. We used a solid state pharyngeal manometer 2.1 mm in diameter, with three pressure transducers measuring 2×5 mm, which were oriented toward the posterior pharyngeal wall, to record pressures in the pharynx and UES. As the catheter reached the posterior aspect of the participant's nasal cavity, the participant was asked to look briefly to the ceiling to reduce the nasopharyngeal angle so that the catheter could be inserted into the pharynx. Then, with the head back to neutral position, he/she was handed a glass of tap water and asked to rapidly drink the water through a straw. In doing so, the distal portion of the catheter was swallowed into the esophagus. The participants were asked to swallow until the catheter was pulled down 30 cm as measured from the tip of the nose. It was then slowly pulled out again until it was in the appropriate location to measure the information needed for this study. When positioned correctly, the first, second, and third sensors recorded pressures from the oropharynx, hypopharynx, and UES, respectively, during swallowing [30]. The M wave [31,32] was observed in the third sensor during swallowing, indicating its correct placement within the UES. When the catheter was correctly placed, it was taped securely to the external nose with adhesive tape.

Lingual swallowing pressures were measured with a three-bulb lingual pressure array placed onto the palatal vault by means of oral adhesive (Stomahesive® strips, ConvaTec, Princeton, New Jersey, USA). The lingual pressure device is a component of the Kay® Digital Swallowing Workstation and measures glossopalatal pressures corresponding to the anterior, middle, and posterior part of the tongue. However, as some participants could not tolerate the posterior sensor, which when the array was secured onto the palate was approximately between the junction of the hard and soft palate, it was removed. Thus, data was recorded only from the anterior and middle sensors. Consistency in placement was established by placing the anterior sensor 5 mm posterior to the incisive papilla [14]. Each sensor was 13 mm in diameter and the spacing between sensors was 8 mm. All data were recorded concurrently with a sampling rate of 1000 Hz.

When the participant was ready, he/she executed five relaxed dry (saliva) swallows, which were taken as baseline measures. Stimuli were then randomly presented: control odor, low odor, high odor, control tastant, low tastant, and high tastant. The odor stimuli were presented continuously for 1 min, then paused for 15 s to avoid