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Pharyngeal pressure differences between four types of swallowing in healthy participants

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HIGHLIGHTS

- Differences in pharyngeal pressure between four types of swallowing were evaluated.
- Pharyngeal pressure differed between swallowing types and bolus types.
- Discrete swallowing produced lower UES pressure than continuous swallowing.
- Discrete water swallowing produced longer UES opening than continuous swallowing.

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ABSTRACT

Purpose: The aim of this observational study was to identify biomechanical differences, as measured by pharyngeal manometric pressure patterns, between discrete and continuous water swallowing, as well as volitionally initiated and reflexive swallowing.
Methods: Using pharyngeal manometry, swallowing-related pressures from 24 young healthy individuals were recorded at three locations: upper pharynx, mid-pharynx and upper oesophageal sphincter (UES) during four swallowing conditions: discrete saliva swallowing, discrete 10 ml water swallowing, volitional continuous water swallowing, and reflexive continuous water swallowing. Measures of peak pressure and pressure duration at each level were compared across conditions using repeated-measures analysis of variance.
Results: UES nadir pressure during saliva swallowing was lower than during water swallowing conditions ($p < 0.05$). In addition, nadir pressure during discrete 10 ml water swallowing was lower than during reflexive and volitional continuous water swallowing conditions ($p < 0.05$). Saliva swallowing produced longer pressure duration than water swallowing conditions at the upper pharynx ($p < 0.05$). Saliva swallowing produced pressure of greater duration than reflexive continuous water swallowing at mid-pharynx ($p < 0.05$). Further, discrete 10 ml water swallowing produced longer UES opening duration and longer pharyngeal pressure generation ($p < 0.05$) than reflexive continuous water swallowing or saliva swallowing.
Conclusion: Pressure generation differs between swallowing types and bolus types at the level of the UES in particular. These physiological differences between swallowing and bolus types may support clinical decisions for individuals with impaired swallowing.

1. Introduction

In most studies of swallowing biomechanics and neural control, outcome measures have been primarily derived from discrete water or saliva swallowing (e.g. [1–3]). Given that discrete liquid swallowing does not represent a typical pattern of fluid intake, it is of interest to evaluate differences between discrete and continuous swallowing.

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Studies have previously addressed this issue by comparing behavioral and mechanical differences observed on videofluoroscopic swallowing study (VFSS) between voluntary, discrete and continuous water swallowing using cup drinking [4] and straw drinking [5, 6]. Continuous swallowing was found to require higher neuromuscular demands to accommodate an increased rate of liquid flow [4]. Increased rate of flow was thought to require a higher level of movement coordination to ensure safe swallowing [4,6]. For example, Chi-Fishman and Sonies [4] reported that laryngeal movement varied during continuous swallowing with most individuals only partially lowering the hyolaryngeal complex (HLC) after each swallow before re-elevation for the subsequent swallow. This movement was interpreted to be essential to accommodate for the greater speed of movement required for continuous swallowing. On the other hand, Daniels and Foundas [6] identified two patterns of HLC movement during continuous swallowing: (i) elevation and lowering of the HLC after each swallow with return of the epiglottis to upright and (ii) continuous partial elevation of the HLC with an inverted epiglottis throughout the continuous swallowing task. The differences in the above findings could be attributed to the two different methods of liquid ingestion (cup vs. straw, respectively). These patterns do not appear to be influenced by age, as both patterns were equally observable in younger and older participants [5].

In the abovementioned studies, outcome measures were based on visual inspection of VFSS; however, VFSS does not provide quantitative data about the timing and pattern of pharyngeal and UES pressure generation. Given the reported biomechanical differences between discrete and continuous swallowing, evaluation of pharyngeal pressure patterns is warranted.

Pharyngeal manometry provides quantification of pressure during pharyngeal swallowing. Information regarding strength and timing of pharyngeal pressure generation and upper esophageal sphincter (UES) relaxation is acquired with excellent temporal resolution [7]. Pharyngeal manometry has been utilized to investigate pressure differences between saliva and discrete water swallowing, both with and without swallowing maneuvers [3]. Data from this study revealed that saliva swallows were produced with significantly higher peak amplitude at the upper pharyngeal sensor only and with significantly longer pressure duration at the upper pharyngeal and middle pharyngeal sensors compared to discrete water swallows. This study, however, utilized discrete swallowing only. It is a common pattern, however, for individuals to drink continuously during the ingestion of liquids; therefore, comprehensive evaluation of swallowing types is warranted to understand how they may affect pharyngeal pressure. In addition, the above-mentioned studies tested volitional swallowing; however, no study has compared the differences in pharyngeal pressure generation between volitional and reflexive swallowing. Such information is important to understand swallowing kinematics between various methods of liquid ingestion and may assist in guiding clinical decisions.

In the present study, we expanded on this literature by employing pharyngeal manometry to quantify difference in pharyngeal pressure generation patterns across four swallowing conditions, including a reflexive swallowing task. The aim of this study was to compare pharyngeal pressure generation patterns across four swallowing conditions, including: (a) discrete saliva swallowing, (b) discrete 10 ml water swallowing, (c) volitional continuous water swallowing, and (d) reflexive continuous water swallowing. It was hypothesized that there would be significant differences in pharyngeal pressure generation patterns between the four swallowing types with saliva swallowing producing higher pharyngeal peak pressures than water swallowing conditions, saliva swallowing producing longer pressure duration than water swallowing, continuous water swallowing producing shorter pressure durations compared to discrete water and saliva swallowing and reflexive swallowing producing shorter pressure durations than volitional swallowing.

2. Methods

2.1. Research participants

Twenty-four healthy volunteers (12 males, mean age = 24.4, SD = 6.3) were recruited through written advertisement. All participants reported no significant medical history or current symptoms of dysphagia, no neurological impairments, and no drug use that could potentially affect their neurological function. The inclusion criteria were confirmed using a medical history questionnaire. This project received ethical approval from the appropriate regional health research ethics review board.

2.2. Procedures

After informed consent was obtained, research participants were seated in a comfortable chair in an upright position. A manometric catheter housing three pressure sensors (Gaeltec Pressure Transducer Model CTO/2E-3, 2.1 mm in diameter) was used to record pharyngeal pressure dynamics. The manometric catheter housed solid-state, unidirectional, posteriorly-oriented sensors spaced 20 mm between sensors one and two and 30 mm between sensors two and three.

To facilitate catheter insertion, the catheter was lubricated (Lube Gel, Unitrade International NZ Ltd, Auckland) and inserted transnasally. Once the catheter reached the pharynx, participants drank water through a straw until the catheter was swallowed to approximately 40 cm from the tip of the nose into the esophagus. Gentle pull-through was applied until the appearance of a prototypical “M” wave on the UES sensor (lowest sensor) during swallowing which indicated placement of this sensor on the superior border of the tonically contracted UES [8]. The orientation of the manometric sensors toward the posterior pharyngeal wall was confirmed by continuous monitoring of the unidirectional markers on the catheter. The catheter was appropriately placed with the proximal manometric sensor (sensor 1) located approximately in the oropharynx, the middle sensor (sensor 2) in the mid-pharynx and the distal sensor (sensor 3) at the upper margin of the UES. Upon confirmation of correct placement, the catheter was secured to the tip of the nose with medical tape to ensure continued correct placement.

After preparations were completed, the participants were given 5 min to adjust to the manometric catheter in situ. The participants were then instructed to execute the experimental tasks, as described below, in randomized order without visual feedback to guide their performance. Data were stored on an integrated swallowing workstation (Kay Elemetrics Digital Swallowing Workstation) for offline analysis.

2.3. Experimental tasks

Participants completed five blocks of four swallowing tasks in randomized order. In each block, participants performed five discrete saliva swallows, five discrete 10 ml water swallows, and both volitional continuous swallowing and reflexive continuous swallowing for 7 s. For the discrete saliva swallowing task, participants performed five non-effortful saliva swallows at the rate of one swallow approximately every 30 s. The instructions were: “gather your saliva and when I say ‘go’, swallow your saliva as you normally do”. The participants performed five swallows at a rate of approximately one swallow every 30 s. The instructions were as follows: “when I say ‘go’, use the straw to drink the water in one swallow”. Participants performed the volitional continuous swallowing task by drinking from a cup containing 190 ml of room temperature water through a straw. The instructions were: “when I say ‘go’, quickly drink the water through the straw continuously until I say stop”. For both the discrete and continuous volitional swallowing tasks, the examiner held the cup and straw up to the participant's mouth in order to prevent changes in head or neck positioning. Finally, for the reflexive, continuous swallowing condition,