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Examination of swallowing maneuver training and transfer of practiced behaviors to laryngeal vestibule kinematics in functional swallowing of healthy adults

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HIGHLIGHTS

- First study to describe the occurrence of LVC transfer when comparing pre, during and post-training outcomes.
- Outcomes indicate it is possible to manipulate and hasten swallowing airway protection (LVCrt).
- Outcomes also indicate that manipulation of LVCrt can transfer to natural swallowing.
- LVC reaction time was significantly shorter both during vLVC training period and post-training in 5 ml natural swallows.

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ABSTRACT

Swallowing maneuvers are routinely trained in dysphagia rehabilitation with the assumption that practiced behaviors transfer to functional swallowing, however transfer is rarely examined in the deglutition literature. The goal of this study was to train the volitional laryngeal vestibule closure (vLVC) maneuver, which is a swallowing maneuver that targets prolonged laryngeal vestibule closure (LVC). In two different training experiments, 69 healthy adults underwent Long-hold (hold vLVC as long as possible) or Short-hold vLVC training (hold vLVC for 2 s). Before and after vLVC training, natural swallows (swallowing without a therapeutic technique) were completed. The outcome variables included laryngeal vestibule closure reaction time and the duration of laryngeal vestibule closure. Results indicate that during both Long-hold and Short-hold vLVC trainings, vLVC swallows had faster laryngeal vestibule closure reaction times and longer durations of laryngeal vestibule closure than in pre-training 5 ml liquid swallows. However, only faster laryngeal vestibule closure reaction times transferred to post-training 5 ml liquid swallows (20–24% faster), but not prolonged durations of laryngeal vestibule closure. Our findings suggest that swallowing maneuver training has the potential to induce transfer of what was practiced to functional swallowing behavior, although not all practiced behaviors may generalize. These findings are significant for bolstering the effectiveness of dysphagia management in medical settings and should be tested in individuals with dysphagia.

1. Introduction

Airway protection during normal swallowing is primarily accomplished by laryngeal vestibule closure (LVC), which involves intricate coordination of several oropharyngeal structures. The kinematic events involved in LVC include epiglottic inversion, hyo-laryngeal elevation, aryepiglottic fold bunching, arytenoid adduction and forward pivoting, base of tongue posterior movement, and pharyngeal constriction [10,12–14,27,36].

Swallowing maneuvers are prescribed in dysphagia therapy to target impaired airway protection, because they involve volitional modifications to the timing and extent of some structures involved in swallowing [26]. They may target prolonging hyo-laryngeal elevation

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during a Mendelsohn maneuver [21] or arytenoid adduction and true vocal fold closure during a supraglottic swallow [5,32]. Swallowing maneuvers are distinct from functional oropharyngeal swallowing, which does not emphasize modification of any particular component of the swallow, but serves simply to move saliva, liquids, or foods into the esophagus. We will refer to functional oropharyngeal swallowing as *natural* swallows throughout this manuscript.

1.1. Transfer of swallowing maneuvers in dysphagia rehabilitation

Despite the known physiological modifications that can be achieved with swallowing maneuvers, the swallowing research literature does not adequately address the important rehabilitation goal of transferring these learned therapeutic gestures to functional, non-therapeutic behaviors (i.e. leg strengthening exercises transfer to walking). Transfer is characterized simply as a trained behavior that affects an untrained behavior [19]. This rehabilitation goal of transference is partially derived from a key principle of motor learning, wherein learning is primarily proven when a practiced behavior transfers to a different task or sensorimotor system [25,42,44]. Transfer has two components including *generalization* (trained behavior is applied to different settings or tasks) and *maintenance* (transference is persistent over time) [3]. Given the gap in knowledge regarding immediate effects of swallowing training, it seems that generalization is a critical first step toward establishing the presence of transfer of swallowing maneuvers to natural swallowing. To test generalization, swallowing scientific experiments should examine behaviors before, during and after a target training. This is needed in order to understand (1) whether the swallowing maneuvers that were trained are different than natural swallowing (pre-training versus training) and (2) to determine if post-training swallowing is affected by training (pre-training versus post-training). However, according to Macrae and Humbert [30] much of the swallowing treatment literature reports data on behaviors observed either (a) during the training period or (b) before and after the training.

1.2. Goal and significance of the current study

The current manuscript describes two experiments that investigate whether training a novel swallowing behavior transfers to natural swallowing immediately post-training. Specifically, we examined transfer when training the volitional laryngeal vestibule closure maneuver (vLVC). The vLVC maneuver begins with a swallow and requires prolonging LVC for at least 2 s, thus LVC prolongation is directly targeted with the vLVC maneuver [2,29]. We aimed to determine whether LVC modifications made during vLVC training transfer to functional swallowing behavior, by comparing LVC timing among pre-vLVC training, vLVC training, and post-vLVC training swallowing in healthy adults. We hypothesized that post-training water swallows would have longer LVC durations than pre-training water swallows, given the focus of LVC prolongation during vLVC training. The outcome of this study is significant because it begins to address a relevant, published concern that dysphagia exercises may not lead to improvement of swallowing function [22,23]. Understanding whether swallowing maneuver training can immediately transfer to natural swallowing behavior post training (generalization) is a critical first step toward improving the efficacy of dysphagia rehabilitation.

2. Methods

2.1. Experiments

Two experiments were conducted to test our hypothesis that transfer can occur in healthy adults who train a swallowing maneuver. Both experiments involved a pre-, during, and post-training phase as well as a timed vLVC performance task. In the *Long-hold vVLC training*, participants were asked to prolong the vLVC swallow for as long as possible. In the *Short-hold vVLC training*, participants were asked to perform a 2-second vLVC swallow. The Long-hold and Short-hold trainings were not designed for direct comparison. Our goal is to report findings from these two different vLVC training protocols to provide a richer understanding of whether and how vLVC training influences the presence or type of transfer to functional swallowing.

2.2. Participants

This study included 69 healthy adult participants in total, including 34 individuals who participated in the Long-hold vLVC training (mean age 27 yrs $\pm$ 11) and 35 who participated in the Short-hold vLVC training (mean age 35 yrs $\pm$ 14). The subjects had no history of speech, respiratory, or swallowing problems and data from 51 of these participants were previously reported to test a different hypothesis in Macrae et al. [29] and Azola et al. [2]. The local Institutional Review Board (IRB) approved the study and all participants provided written informed consent prior to participation.

2.3. Procedures prior to training for both experiments

All participants were required to demonstrate their first accurate performance of the vLVC swallowing maneuver in order to participate in any vLVC swallow training. The vLVC swallow maneuver began with a saliva swallow, followed by volitional prolongation of LVC duration for at least 2 s (view vLVC maneuver here: https://www.youtube.com/watch?v=hiPbGsnNj8s). Two seconds is the threshold for accurate vLVC performance because it is approximately three times longer than the duration of LVC in a natural swallow of healthy adults [34], indicating that volition was needed to prolong closure. Participants were taught to perform the vLVC for the first time with instructions to swallow saliva and palpate the thyroid notch (aka Adam's apple) to detect its upward movement. Then, they were instructed to swallow again and hold the thyroid notch up as high and long as possible. In addition, participants were told that they should not be able to breathe during this short period. These instructions were followed by videofluoroscopic recordings of vLVC swallow maneuver attempts to allow the investigator to confirm the first accurate performance. Participants were only advanced to vLVC training if they performed the vLVC maneuver accurately within 5 attempts. In previous studies, most participants needed <5 attempts to achieve the vLVC maneuver [2,29]. Five attempts allowed adequate trials to demonstrate the maneuver without using gratuitous videofluoroscopy time, which was limited for participants' safety and to ensure adequate time to record the remaining trials of the study. All swallows in all phases were recorded with videofluoroscopy and verbally cued by the investigator to synchronize the onset of videofluoroscopic recording with swallowing. Each vLVC trial was performed with saliva rather than a bolus, although participants were permitted 1 ml water boluses during the inter-trial intervals trials to maintain enough oral moisture to initiate a swallow. The inter-trial intervals were approximately 30 s throughout both trainings.

2.4. Procedures for the Long-hold vLVC swallow training

Prior to Long-hold training, five participants could not achieve the vLVC maneuver and were excluded from vLVC training. These individuals, who we refer to as “Learners”, were permitted to continue to attempt to achieve the vLVC maneuver for a total of 15 trials instead of vLVC training. The remaining 29 participants completed the Long-hold training. The Long-hold vLVC training included three phases in the following order: (1) pre-vLVC training natural swallows (water), (2) vLVC training swallows (saliva), and (3) post-vLVC training natural swallows (water). The study designs for Long-hold and Short-hold experiments are shown in Fig. 1.