Effects of Straw Phonation Through Tubes of Varied Lengths on Sustained Vowels in Normal-Voiced Participants

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Summary: Objective. To examine the immediate effects of straw phonation exercises in normal subjects while altering the effective length of the vocal tract.

Study Design. A nonrandomized comparison of semi-occluded vocal tract length during straw phonation exercises was carried out.

Methods. Oral pressure, mean airflow, aerodynamic resistance, and contact quotient were measured in 20 healthy subjects immediately before and after straw phonation exercises. A short- and long-duration phonatory task was used to examine the voice parameters during semi-occluded vocal tract exercises. These tasks involved repeating a vocalization of the vowel /a/ through a tube. Each subject underwent the protocol using tubes of three different lengths (7.5 cm, 15 cm, and 30 cm) to allow for the effect of moving the outlet of the vocal tract distal to the mouth to be monitored.

Results. Oral pressure and aerodynamic resistance decreased significantly, contact quotient showed a decreasing trend, and airflow increased significantly in pre- and postmeasurements 15 minutes after a long-duration phonatory task. Short-duration tasks were found to have no effect on voice parameters.

Conclusion. The results present and validate a method to isolate the effect that the length of a semi-occluded vocal tract has during straw phonation exercises.

Key Words: Straw phonation–Voice therapy–Vocal tract–Impedance–Human subject.

INTRODUCTION

Voice disorders impair work performance and quality of life, and approximately 28 million workers in the United States require their voice for employment.[1] The prevalence of voice disorders demands accessible and noninvasive vocal therapy.

Semi-occluded vocal tract (SOVT) therapy is a noninvasive treatment for voice disorders that improves vocal economy, efficiency, and intensity. Variations include hand over mouth, lip and tongue trills, Y-buzz, bilabial fricatives (eg, [β:]), nasal consonants (eg, /m/, /n/, /ɛ/), resonance tubes, and straws.[2] Mouth semi-occlusions, such as bilabial fricatives, lip trills, /u/ vowels, and straws produce resonant voice. Resonant voice is a target for vocal production because it does not cause excessive mechanical stress to laryngeal tissues or result in poor harmonic content. Further, it also provides a more effective conversion of aerodynamic to acoustic energy.[3]

During phonation, the glottis is opened when the vocal tract's air column is accelerated by increased glottal flow, resulting in a positive supraglottal and subglottal pressure. This coupling results in a positive intraglottal pressure that pushes the vocal folds apart.[2–5] Supraglottal pressure becomes negative during the closing phase, creating a suction that pulls the vocal folds apart.[2–5] The strength of this push-pull interaction is determined by the acoustic impedance of the vocal tract.[2–5] Impedance consists of resistance, which removes energy from a system, and reactance, which stores and feeds energy into a system. Reactance can further be broken down into positive and negative components. The positive component, inertive reactance, produces a time-delayed buildup of supraglottal pressure, strengthening the push-pull relationship that facilitates self-sustained oscillation.[2–5] High inertance is therefore desired as it leads to greater amplitude of vocal fold vibration which increases source strength in the nonlinear source-filter interaction and allows for easier phonation.[6] A schematic which breaks down the components of acoustic impedance can be seen in Figure 1.

Impedance matching seeks to lessen tissue collision and thus cause improved voice production. The most efficient transfer of power from the source-filter interaction, glottis to lips, occurs when source impedance is matched to vocal tract input impedance.[7] Impedance is altered in straw phonation by having a patient phonate through a tube that alters both the effective length and outlet diameter of the vocal tract. These alterations to the effective vocal tract can improve vocal economy and vocal efficiency. Vocal economy is a measurement involving voice output and intraglottal impact stress and helps to maintain resonant voice and inertive reactance.[8] High vocal economy is obtained when voice output is high while intraglottal impact stress remains low.[8] Intraglottal impact stress, which is defined as the impact force of the vocal folds during phonation divided by contact surface area of the vocal folds, is a common cause of vocal lesions.[8–10] Vocal efficiency is a quantitative measurement that involves the conversion of subglottal energy to acoustic energy.[11,12] With higher efficiency, less effort is needed to produce vocalizations.[11,12] Improving both vocal economy and vocal efficiency can therefore lead to healthier voice production.

The effects of various dimensions of tubes used for straw phonation have been studied in both excised laryngeal and other simulated systems. Smith and Titze developed an experimental setup to characterize the effects of tubes of various diameters

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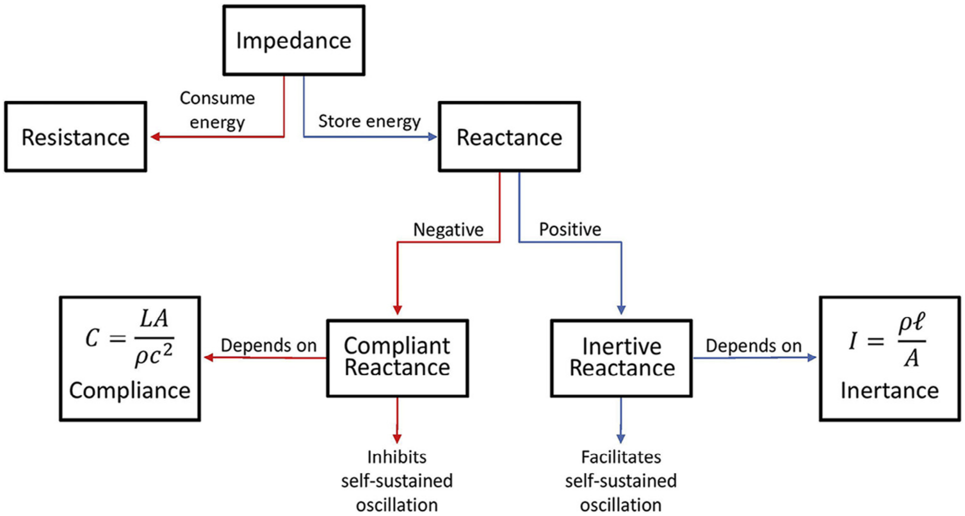

FIGURE 1. Schematic of the components of acoustic impedance. The inertive and compliant components of reactance depend on frequency of the acoustic signal and the proportionality constants: inertance and compliance, respectively. I, inertance; C, compliance; ρ, density of air column; L, length; A, cross-sectional area; c, speed of sound in air.

and lengths.[13] Using four lengths divided equally from 3 cm to 24 cm, they were able to characterize differences in airflow (AF), pressure, and resistance for these different tubes. Conroy et al. used lengths within a similar range, specifically 7.5, 15, and 30 cm, in an excised laryngeal setup.[14] They found a significant decrease in phonation threshold pressure from control, when using the 30-cm tube. These studies have been referenced to determine the range of interest when evaluating the effect of the length of the tube used for straw phonation.

Studies have examined the effects of different SOVT dimensions across multiple therapy methods in human subjects.[15,16] Further, no human subject studies have altered only length or diameter while leaving the other constant. By evaluating only the length of the SOVT used for straw phonation, a more precise quantification of the physical changes observed may be found. The purpose of this study is therefore to observe the isolated effects of tube elongation on straw phonation exercises in healthy-voiced subjects. We hypothesized that vocalizations following SOVT exercises will be characterized by differences in aerodynamic and electroglottograph (EGG) parameters. Extended duration SOVT tasks will result in significantly greater changes in parameters than short-duration tasks.

METHODS

Subjects

A total number of 20 subjects (10 men, 10 women) volunteered for this study. Participants included undergraduate and graduate students from the University of Wisconsin-Madison. Recruitment was carried out by placing fliers in campus facilities. The inclusion criteria were as follows: (1) nonsmoking, (2) above the age of 18, and (3) having no history of diagnosed voice disorders or other pertinent medical conditions (polyps, nodules, laryngitis, etc). Before data collection, the Institutional Review Board of the University of Wisconsin-Madison approved all procedures.

Data collection

Data collection of this study consisted of a short- and long-duration phonatory task, both of which are minimal risk tasks. There were three different tube lengths evaluated in this study: 7.5 cm, 15 cm, and 30 cm PolyVinyl Chloride tubes, each with a diameter of 2 cm. For each tube length, both the short- and long-duration tasks were completed on the same day. However, the three lengths were completed on three separate days within a period of 2 weeks. This isolated the effects of each condition, while also ensuring each subject's quality of voice was similar across their 3 days of data collection.

Before initially starting the short-duration task, each patient was given a training session on the equipment and the vocalizations they would be performing. This was carried out by performing a demo of data collection for each subject. After this, subjects were asked to get comfortable with the equipment by performing test vocalizations. Once they were consistently able to perform vocalizations with similar pitch and loudness, they were allowed to move on to the short-duration task.

The short-duration task required the participant to perform 12 repetitions of the vowel sound /u/ through the SOVT for 5 seconds in duration, with a 3-second break between each trial. The long-duration version of this task required the subject to repeat the short-duration task 10 times sequentially with a 30-second break between iterations. Throughout the length of the study, participants were instructed to produce the pitch and loudness that is most comfortable while directing all the sound through the SOVT.

Measurements of oral pressure, mean AF, mean aerodynamic resistance (AR), and contact quotient (CQ) were taken before and after each task for each tube length. EGG measurements were obtained using a two-channel electroglottograph with a microphone preamplifier (EG2-PCX2, Glottal Enterprises, Syracuse, NY), whereas aerodynamic measurements were obtained with the Phonatory Aerodynamic System (PAS Model 6600, KayPENTAX, Montvale, NJ). No custom equipment or software was used to collect data. Subjects were asked to complete