PROLONGED EFFECT OF SOVT ON PHONONORMALS: STRAW PHONATION TECHNIQUE

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A Dissertation Submitted in Part Fulfillment of Degree of Master of Science
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July 2020

CERTIFICATE

This is to certify that this dissertation entitled "**PROLONGED EFFECT OF SOVT ON PHONONORMALS: STRAW PHONATION TECHNIQUE**" is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 18SLP020. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for award of any other Diploma or Degree.

Mysuru

July 2020

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July 2020

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DECLARATION

This is to certify that this dissertation entitled "**PROLONGED EFFECT OF SOVT ON PHONONORMALS: STRAW PHONATION TECHNIQUE**" is the result of my own study under the guidance of Dr. K Yeshoda, Associate Professor, Department of Speech Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for award of any other Diploma or Degree.

Mysuru ***Registration Number: 18SLP020***

July 2020

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Dedicated to my loving grandparents, Daji and Didi.

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CHAPTER 1

INTRODUCTION

According to the Merriam-Webster dictionary, voice, simply put, is the sound emitted by the larynx of any organism. But the human voice is so much more complicated than just 'sound' because it provides an identity for each individual. The lungs provide the power for vocal fold vibrations, the vibrations of the same give rise to a sound altered by the filter characteristics of the vocal tract. In many ways, voice can be thought of as unique to an individual as their fingerprint (Stemple, Gerdeman & Klaben, 2000). According to West (1956), normal voice has adequate loudness, clearness, and which is appropriate to age and gender and is pleasant to hear.

A professional voice user is one who depends on their voice for their livelihood. The 'elite' professional voice users include playback singers, classical singers, opera artists, film and theatre actors. The non-elite professional voice users include other occupational voice users, such as, teachers, sales executives, and even speech-language pathologists (Kauffman, 1991). Mild to moderate aberrations in the voice of professional voice users can severely impact their quality of life.

Professional voice users being the 'challenging and diverse' population as they are, it is essential to fully understand the anatomy and physiology of voice production (Courey, 2003), and come up with intervention and prevention guidelines that are easy to implement, and proven to be powerfully effective through age-old practice.

SOVTEs in Singers

Semi-occluded vocal tract exercises, particularly straw phonation, have historically been linked to a vocal warm ups and have been practiced by singers for ages, starting, of course, with 'Finnish tubes' and then moving on to more readily available rigid/flexible plastic straws. However, only recently did the focus shift to examining the clinical effects of straw phonation exercises and studies came about to investigate the acoustic, aerodynamic, and glottal parameters of singers (Titze, 2006).

In a study assessing the glottal parameters, acoustic, perceptual, and subglottal measures of a male trained classical singer before, during and after the performance of 5 minutes of tube phonation and straw phonation, it was found that subglottic pressure increased during, and persisted after straw phonation. In contrast, only the latter effect was observed in tube phonation. LTAS analysis revealed an increase of 2.5 dB in the singer's formant cluster after straw phonation. There was a more significant reduction in the first formant value after straw phonation, than after tube phonation. Four impartial judges unanimously agreed that voice quality improved, after straw phonation, whereas such a degree of agreement could not be reached in tube phonation. The Contact Quotient values decreased after both exercises, but the decrease was more significant in straw phonation than tube phonation. The authors explained the decreased CQ as a result of the reduced vocal fold impact stress due to semi-occlusion. The authors also mused about the possible therapeutic effects of a long term practice with straw phonation, including better velar closure, pharyngeal region widening, and reduced tension in individuals with vocal hyperfunction (Guzman et al., 2013).

In another study, videostroboscopic and endoscopic examinations on 4 singers after 3 trials of each of straw phonation, lip trill, and tongue trill revealed that though there was not one single SOVTE that benefited all four singers, all the participants benefited from at least one of the exercises. In one of the singers, the significant medial-lateral constriction of vocal folds, as seen in the pre-SOVTE condition, was eliminated, as was the pharyngeal constriction. It led the authors to believe that practising tongue trills can reduce phonatory effort, and supraglottic constriction can altogether disappear with lip trills and tongue trills. In two of the singers, the mucosal wave pattern and phase closure of vocal folds showed considerable improvement, further reinstating the belief that SOVTEs can bring about beneficial changes in practitioners (Dargin, Delaunay, Searl, City, & City, 2015).

Similar to the previous study, the same authors examined the immediate effects of practising three kinds of SOVTEs, namely, the lip trill, tongue trill and straw phonation on a few aerodynamic and electroglottographic parameters. The results indicate that aerodynamic measures like sound pressure level and airflow are liable to show an immediate increase in singers, after practicing SOVTEs. The aerodynamic and EGG changes observed, however, were subject to variability within and across the participants (Dargin & Searl, 2015).

Kaneko, Sugiyama, Mukudai, and Hirano (2019) investigated the effects of SOVTE on eight singers and eight non-singers. 12-week-long sessions, which consisted of four different types of semi-occluded vocal tract exercises, including tube phonation, were carried out. Lung pressure during expiration and as well as perturbation measures such jitter and shimmer exhibited significant improvement in the post-therapy assessment in both the singers and non-singers group.

Manternach and Daugherty in 2019 investigated the effects of straw phonation therapy on acoustic and self-report measures of 48 choir singers consisting of 15 soprano, 10 altos, 8 tenor, and 13 bass singers, aged between 17 to 56 years. Though LTAS measurements revealed little difference in mean spectral energy, before and after the straw phonation protocol, the questionnaire responses suggest that the participants perceived betterment in their voice production as well in the overall sound of the choir.

On a similar note, Manternach, Schloneger, and Maxfield (2019) found that both an experimental and control group consisting each of 11 women's choir singers, displayed higher mean spectral energy after completion of a straw phonation protocol (by the experimental group), and a neutral, unoccluded /a/ vowel protocol (by the control group). The authors recommended the use of straw phonation exercises by music educators to reduce vocal effort and improve vocal output. Thus, straw phonation was shown to have beneficial effects in terms of reduced vocal effort and improved quality of voice in elite voice users such as professional singers.

SOVTEs in Geriatric Population

The aging voice exhibits reduced intensity, and more variations, than the normal voice. Previous literature has suggested the practice of Vocal Function Exercises to reduce the effects of age on vocal quality (Gorman, Weinrich, Lee, & Stemple, 2008), as well as the use of physiological therapy programs such as Lee Silverman Voice Therapy have been proved to increase loudness and perceived voice quality in geriatric individuals (Ramig et al., 2001). However, Guzman et al. (2018) hypothesized that since Water Resistant Therapy (phonation into a tube, with the other end immersed in water) has been shown to cause an increase in subglottal pressure, and also increase in the glottal parameter Contact Quotient, it might produce similar effects for presbyphonia. The authors studied how some acoustic, aerodynamic, and glottal parameters in the geriatric population may immediately be affected by water resistant therapy study. The subjects consisted of 30 elderly individuals with a mean age of 73, who exhibited improved glottal closure, and aerodynamic characteristics as indicated by a significant increase in Contact Quotient, subglottal pressure, and SPL, immediately after performing WRT. Thus, the authors recommend the use of tube phonation into water to improve the effectiveness and quality of voice in individuals with presbyphonia.

SOVTEs in Pediatric Population

Ramos and Gama (2017) studied how straw phonation affected the voice quality of twenty-seven children with dysphonia aged between 5 to 10 years. 25 of them were diagnosed with vocal nodules, and 2 of them had 'epidermoid vocal fold cyst'. Acoustic and auditory perceptual evaluations were carried out immediately before, and at the 1st, 3rd, 5th, 7th minutes of straw phonation exercise. The GRBAS scale was used for auditory perceptual evaluation. For acoustic analyses, the parameters obtained from a task of prolongation of vowels were fundamental frequency, jitter, shimmer, glottal to noise excitation ration (GNE) in dB, and noise in dB. The participants were found to have improved voice quality after straw phonation, in terms of improved roughness and breathiness parameters, and as well as overall grade of dysphonia.

Need for the Study

The clinical goal of using a SOVT posture is to achieve higher vocal output (efficiency) with less vocal fold impact stress and physical effort (economy), ultimately functioning to prevent or lessen the risk of injury to the vocal fold mucosa (Croake, Andreatta, & Stemple, 2017). The voice has more 'harmonic content' when the vibration of the vocal folds is strengthened by an inertive vocal tract, as seen during a semi-occluded vocal tract posture (Titze, 2001). Thus, extensive studies demarcating the physiological and physical underpinnings of semi occluded vocal tract exercise is available in literature (Titze, 1993), but what is lacking is the amount of information on all the kinds of SOVTEs available. While straw phonation and Lax Vox have received much attention, we still are not sure of the long term effects of tongue trill exercise separately, or the effectiveness of one against the other. They are easy to do after a simple demonstration and do not need any tools. Since SOVTEs are being implemented in therapeutic setups in India rapidly, it is necessary to investigate the long term effects of each of these exercises to gain an approximation of normative values. There can be large increments in lung pressures without cause for concern, which has the advantage of warming up the respiratory muscles without causing excessive vocal loading (Kapsner-Smith, Hunter, Kirkham & Cox, 2015). This can lead to better ideas for recommending such exercises for different dysphonic populations. This study will shed light on the outcomes of flow resistant therapy exercise protocols and help us to highlight the effects of 'repeated practice' and long term effects (Rosenberg, 2014; Titze, 1993, 2006).

The following six exercises, namely straw phonation, cup phonation, bilabial fricatives, lip & tongue trills, resonant voice therapy, and lastly open and closed vowels, progressing from those having the 'greatest effect, but most artificial' to 'smallest effect, but closest to natural' was proposed by Titze (2006). He suggested that not only can straw phonationthat be practised easily and regularly outside clinical settings, but also it draws little attention to itself, can be done quite literally, anywhere, and the coveted effect of optimal glottal source and vocal tract filter is accomplished in a short duration. The benefits of such exercises could lead to effective voice production strategies to warrant recommending them for different dysphonic populations.

The present study was planned to understand and measure the outcome of prolonged effect of one of the SOVTE, namely, the Straw Phonation Technique on phononormal individuals. Such a study will shed light on the outcomes of "Straw Phonation" therapy exercise protocols and help us to highlight the effects of 'repeated practice' and long term effects.

CHAPTER 2

REVIEW OF LITERATURE

The process of production of voice can be simplified into just the transformation of aerodynamic energy to acoustic energy, which then is perceived as vocal sound. When that acoustic energy meets a constriction in its path, a part of it is redirected towards the source of the sound, that is, the vocal folds, forming a backpressure and an 'unpressing' of the same. An impedance match between the source and the filter leads to better and more effective transformation of aerodynamic to acoustic energy (Rosenberg, 2014).

The impedance can be measured by dividing the acoustic pressure in the filter (vocal tract) by the glottal airflow, in voice science. The stimulus is the glottal airflow which acts as the stimulus, and it creates momentum and acceleration (response) to the air column (acoustic pressure) in the vocal tract (Rosenberg, 2019). The quality of voice varies with the timing and coordination of this event.

With the lack of a timely response to the stimulus, there arises what is called reactive impedance or reactance. When there is an advanced response, it is called compliant reactance and when there is a delayed response it is known as inertive reactance. Inertive reactance gives rise to a resonant voice production because of more efficient conversion of aerodynamic energy to acoustic energy. Voice therapy aims at facilitating areas of inertive reactance along the vocal tract to give rise to an highly efficient voice production. Semi occluded vocal tract exercises provide a simple and easy way to create more inertive areas in the vocal tract (Rosenberg, 2014).

The body of speech pathology literature has clearly outlined the effectiveness of semi occluded vocal tract exercises in reducing hyperfunctional phonation (Croake et al., 2017). Voice therapists strive to achieve the kind of quality that SOVTEs promote: just the right balance between breathy and pressed voice. Not only have SOVTEs been prescribed as means to reduce the symptoms of vocal disorders like vocal nodules, fatigue, and recurrent laryngeal nerve paresis, they aid in warm ups in professional voice users by engaging their breathing mechanism (Meerschman et al., 2019). SOVTEs alter the vocal tract length thereby leading to the much coveted impedance match between the filter or the vocal tract and the source, or the vocal folds. This impedance matching creates a backpressure to the glottis as its vibrations sync with the supraglottal pressure and airflow. Studies suggest that even phononormal individuals produced louder, more pleasant, and more resonant voices after SOVTEs. The vocal tract resonance leads to the proper synchronization of the supraglottal acoustic pressures with the glottal vibration, creating a stronger and more resonant voice. Additionally, SOVTEs incur significant acoustic changes in the voice, in the form of lowering the first formant, and bringing together the third, fourth and fifth formants (Andrade, Wood, Ratcliffe, Epstein, Pijper, Svec, 2014).

Vocal economy is said to have been achieved when a voice with sufficient strength and loudness, is produced with relatively low stress inflicted on the vocal folds due to prolonged periods of use, or vocal loading. SOVTEs achieve greater vocal economy by narrowing the epilarynx close to the vocal folds, hence creating a semiocclusion on the vocal tract. Higher amplitudes of the oscillating supraglottal pressure feed the glottis with more energy, allowing higher SPL with relatively less vocal loading. Even the phonatory threshold pressure was reportedly lowered, as a direct function of the reduced epilaryngeal cross-sectional area facilitated by practising SOVTEs (Andrade et al., 2014).

SOVTEs and Their Mechanism

Semi-occluded vocal tract (SOVT) exercises, simply put, involve narrowing at any supraglottic point along the vocal tract in order to maximize interaction between vocal fold vibration (sound production) and the vocal tract (the sound filter) and to produce resonant voice. Their efficacy has been proved over the years successfully, and while performing these exercises, several phenomena take place in conjunction, according to Titze (2006), "the upper part of the vocal folds are spread apart, the medial surfaces of the vocal folds become parallel without pressing the vocal folds together, the phonation threshold pressure is reduced, as are their vocal fold vibrational amplitude and collision forces, which allow lung pressure and fundamental frequency to be taken high in a pitch glide. In practitioners, these effects occur at the same time without the need for much voluntary adjustment, as the system is a self regulating one. The contact stress between vocal folds remains maintained at a low value".

Vocal economy during phonation is optimal with 'barely abducted vocal folds' (Calvache, Guzman, Bobadilla, & Bortnem, 2019). Since impact stress caused due to vocal loading and poor vocal economy is one of the leading reasons for hyperfunctional voice disorders (Calvache et al., 2019), and the electroglottographic contact quotient is indicative of the extent of impact stress (Verdolini, Chan, Titze, Hess, & Bierhals, 1998), it will be a valuable parameter to assess post SOVTE effects. Lip trills have been found to produce markedly lower contact quotient values compared to other SOVTEs (Andrade et al., 2014). Gaskill & Quinney (2012) have argued that lower Contact Quotient values were due to the higher subglottal pressure compensating for the secondary obstruction of the vocal tract. It would be interesting to see if these effects persist with repeated practice.

Calvache et al., (2019) tried to estimate the effects of eight different semi-occluded vocal tract exercises on vocal economy measured by the electroglottographic parameter, the Quasi Output Cost Ratio (QOCR) and found significant post-practice results regardless of voice condition (normal or dysphonic). They concluded that SOVTE help in improving vocal economy, by reducing the impact stress on vocal folds.

Though the effects of SOVTE have been extensively delineated throughout literature, we are still unsure about which SOVTE may be best suited for which person or vocal pathology. The various types of SOVTE that exist, such as, lip and tongue-trills, hand-over-mouth, flow resistant therapy, LaxVox among others add to the problem at hand. Despite the clear benefits that SOVTE provide, such an enhanced voice quality as well as gentler phonation, their implementation and their effects on the vocal physiology can widely vary. Some exercises like humming and hand-over-mouth create a semi occlusion at the anterior regions of the vocal tract while others lengthen the vocal tract by coupling with resonance tubes or straws (Wistbacka et al., 2018).

Laukkanen, Lindholm, Vilkman, Haataja, & Alku (1992, 1996) used the Finnish bilabial voiced fricative [β:] to create a semi-occlusion at the lips for more comfortable phonation. Testing with surface electrodes showed decreased muscle activity for a task of sustained vowels, post exercise with the bilabial voiced fricative. Titze, Finnegan, Laukkanen and Jaiswal in 2002 extended the use of semi-occlusion through the use of straws or flow resistant tubes, their use being advantageous since their diameters can be increased or decreased gradually, depending on the task difficulty required. They found that straw phonation in providing respiratory training to the singers since both the participants raised their lung pressures while phonating into smaller diameter straws. The results also revealed that practice with straws leads to steady vibrational amplitude of the vocal folds across all pitches, and 'pressed' voice could be avoided. Additionally, since phonation into straws creates a semi occlusion near the mouth, the extra length 'further' lowers the first fundamental frequency, leading to an increase in the inertive reactance of the vocal tract, thereby causing the vocal folds and the vocal tract (filter) to interact to an increased extent.

The research carried out in various SOVT exercises have brought to light the effect of practising the same in various parameters of voice, perceptual, acoustic and aerodynamic. When a resonance tube was added to a computational model of the vocal tract Titze and Laurkkanen (2006) identified that the first formant frequency lowered from 300 Hz to 150 Hz. Schwarz & Cielo (2009) used the Sonorous Tongue Vibration Technique (STVT) on vocally normal individuals to study the 'laryngeal impact' and 'sensations arising' after the performance of these exercises. The STVT was found to reduce phonatory effort, making the voice brighter and more resonant and resulting in a marked increase of fundamental frequency. SOVT Exercises may help to re-establish a lower PTP after prolonged phonation or vocal loading (Dargin & Searl, 2015), and even lead to reduced vocal loading (Titze & Flannagan, 2002).

So, in executing the semi occlusives in a maximum beneficial way, one could rationalize those to be used in the order of "greatest effect, but most artificial"" to "smallest effect, but closest to natural" (Titze, 2006). In the hierarchy proposed by Titze (2006), he employed high resistance straw in the foremost position. The flexible straw technique was proposed by Marketta Shivo (2007) and is commonly known as Shivo lax Vox method. The use of rigid straw was proposed by Titze in, 2000 & 2006.

As mentioned earlier, smaller diameter straws have the greatest occlusive effect, thereby having highest resistance, and larger diameter straws have lesser occlusive effects, and has lesser resistance. In a similar way, other semi-occluded vocal tract exercises can fit into this scale of higher resistance to lesser in the order: cup phonation, bilabial fricatives, lip and tongue trills, Resonant Voice Therapy, open vowels and lastly, natural speech posing the least semi-occlusion (Rosenberg and LeBorgne, 2014).

Laukakken et al (2002, 2006) in their studies, recommend the use of acoustic metrics like jitter, shimmer and NHR (noise-to-harmonic ratio) to investigate the effects of SOVTEs. Fantini, Succo, Crosetti, Borragan, Demo and Fussi (2017) reported that some of the most frequently used acoustic measures are perturbation parameters like jitter, shimmer, and noise-to-harmonic ratio (NHR); sound pressure level (SPL); F0; tempo, and vibrato to check for the effects of semi occluded vocal tract exercises, with jitter percent, shimmer percent showing significant changes in the group of singers who practised SOVTEs in their study. They even reported greater phonatory comfort and better perceived voice quality in the experimental group.

A reduction in perturbation measures in a multidimensional acoustic analysis, after repeated practice of SOVTEs will be indicative of a 'stronger, more sonorous' voice, which will also be more 'harmonically rich' (Sampaio, Oliveira, & Behlau, 2008).

SOVTEs in Phono-Normals

Andrade et al, (2014), conducted an electroglottograhic study of the effects of seven semi-occluded vocal tract exercises (Laxvox, straw, lip-trill, tongue-trill, humming, hand-over-mouth, and tongue-trill combined with hand-over-mouth) on 16 participants with no vocal complaints (6 males and 10 females). The authors discovered that semi-occluded vocal tract exercises with a secondary source of vibration (tongue trill, lip trill, LaxVox, and tongue trill with hand-over-mouth), make a difference in the vocal fold vibrations, compared to those with a single source of vibration, such as hand-over-mouth, humming and straw phonation. The participants who practised the SOVTE with a secondary source of vibration exhibited larger CQr (contact quotient range) values, indicating a larger 'massage effect' on the vocal folds, leading the authors to conclude that these exercises may be recommended for those with hyperfunctional voice disorders like muscle tension dysphonia.

Meerschman, Lierde, Peeters, Meersman, Claeys and D'Haesseler (2017) recruited 40 speech pathology students and compared the short term effects of two therapy training programs: resonant voice therapy and straw phonation. The subjects, which consisted of 40 healthy 'future occupational voice users' were assessed before and after a 6 week training program. The assessments consisted of subjective as well as objective analyses. Subjective assessments included self-reports (the Dutch version of the Voice Handicap Index), questionnaires, and auditory-perceptual assessments (using GRBAS scale). The objective assessments included acoustic analyses (using MDVP), measuring the acoustic voice quality index, aerodynamic measures and the Dysphonia Severity Index (DSI). Complying with what literature indicated about straw phonation aiding in production of louder voice with less vocal effort, the DSI showed an increase in intensity range from 35 dB pre-training to 41.1 dB post-training in the straw phonation group. MDVP parameters, such as fundamental frequency, as well as the perturbation measures were positively impacted by the 6 week straw phonation protocol. VHI scores, however, did not show any significant effects after therapy, and neither did the GRBAS reflect any auditory-perceptual differences in the post-therapy measurement. Since both scales were designed for dysphonic voices, the authors explained that they might not be sensitive enough to reflect variations in voice of vocally healthy occupational voice users.

Christmann and Cielo (2016) correlated the acoustic and auditory perceptual measures in 46 adult women with no vocal complaints 5 minutes immediately after performing a kind of SOVTE known as Finger Kazoo, in which phonation is performed with lips protruded and a finger placed lightly upon them, as if in a gesture for 'silence'. MDVP parameters, vAM, DSH and NHR showed a significant reduction post-performance, and results also indicated increased oral air pressure, increased phonation stability, and a significant increase in fundamental frequency within the normal range for females. A continuation study was attempted, and the results of the previous study were compared with those of a group of 12 women who did water resistant therapy (WRT). These data were analyzed using the Multi Dimensional Voice Program Advance and Real Time Spectrogram. The exercises were performed in 3 sets, with 15 repetitions each, and with 30 seconds of passive rest allowed between sets. The WRT group showed more of a reduction in standard deviation of f0 than the Finger Kazoo group. The WRT group also showed a significant decrease in MDVP parameters measured, such as variation in f0 (vF0), smoothed pitch perturbation quotient (sPPQ), and voice turbulent index (VTI). The auditory perceptual analysis did not show any differences between the two groups.

Mills, Rivedal, DeMorett, Maples, and Jiang (2018) investigated the immediate effects of altering the effective vocal tract length of 20 vocally healthy participants by conducting straw phonation exercises. They measured oral pressure, mean airflow, aerodynamic resistance, and contact quotient in their subjects immediately before and after the exercises. The subjects were asked to carry out both long and short duration phonatory tasks, each using three different length of tubes: 7.5 cm, 15 cm, and 30 cm. The results supported previous claims in the existing literature that short duration straw phonation tasks may not bring about any significant effects in voice production. However, 'lingering effects' after the long duration phonation task supported the hypothesis that extended straw phonation exercises will bring about more significant changes in voice parameters. Contact Quotient, too, showed a decreasing trend, indicating an increase in vocal economy with decreased vocal effort.

Kang et al., in 2018, studied the lingering effects of straw phonation on 24 participants with no laryngeal pathology across aerodynamic, electroglottographic, and acoustic parameters. Each of the subjects performed two trials of straw phonation 24 hours apart, for 5 minutes and 10 minutes. They phonated a prolonged steady note, coasted up and down their vocal pitches, and tuned melodically through a straw of measurements 19.5 cm long and 6 mm in breadth. Post-therapy information was derived immediately following the activity, and then after five, ten, fifteen and twenty minutes. A decreased PTP was observed at the fifth minute after straw phonation, which returned to baseline levels within five minutes. However, when straw phonation was practised for a longer duration, like ten minutes, PTP values stayed at lower values for more than five minutes. After both exercise sets, mean air flow rate (MAFR) showed an immediate increase, and stayed at that increased level for the next twenty minutes. Electroglottograph analysis revealed no significant changes, and neither did the acoustic parameters such as jitter, shimmer and fundamental frequency show any significant changes. Therefore, the authors reasoned that 10 minutes of training yields preferred outcomes over that of 5 minutes, and notably, they recommended repeated practice to achieve optimal therapeutic advantages.

Rajasudhakar and Shalini in 2019 looked into the immediate and lingering effects of straw phonation and water resistant therapy, named as steady and fluctuating semi-occluded vocal tract exercises, respectively, in 20 vocally healthy participants. A baseline recording was done using vowel prolongation, and then subjects were instructed to do 5 minutes of straw phonation which included sustained phonation, pitch glides and melodic tuning of the Indian National Anthem. Post-exercise measurements were done immediately afterwards, and then after the 5th, 10th and 20th minutes after the exercise. The same protocol was followed a week apart, for water resistant therapy, or fluctuating semi-occluded vocal tract exercises. The results indicated beneficial effects on acoustic (f1-f0 distance, f0 range) and glottal parameters (SQ and CQ) after both straw phonation and water resistant therapy, and were evident upto 15 minutes after a single session of the respective SOVTE. The authors also suggest that prolonged exercise may have increased and sustained benefits on the voice. The literature review indicates that there are favourable results with a few techniques of SOVTE and immediate effect using some others and prolonged effects when practiced some other SOVTEs. Here an attempt is made to study the effect of 3 weeks of straw phonation on vocally healthy particpants.

SOVTEs in Occupational Voice Users

Meerschman et al., (2019) investigated the effects of three different types of semi-occluded vocal tract exercises: lip trill, water resistant therapy and straw phonation, on 35 patients with dysphonia, which included teachers, and professionals who needed a substantial use of their voice in their daily lives. The therapy sessions spanned over a period of three weeks, with two thirty-minute sessions per week. Assessments which were carried out included objective assessment on Acoustic Voice Quality Index, Dysphonia Severity Index, subjects' self-reports, and auditory perceptual assessments. Straw phonation led to a 'significant decrease in grade and roughness' in perceptual evaluations, thus leading the authors to suggest that straw phonation may to lead to an improvement in 'objective voice quality'. There was a significant decrease in the psychosocial impact as measured by the Voice Handicap Index in the participants practising lip trills and Water Resistant Therapy. However, the authors cautioned generalization of the results due to the small sample size and the relatively short duration of practice.

Aim

To investigate the effect of one semi occluded vocal tract exercise therapy protocols: flow resistant therapy/ straw phonation on normal voice.

Objectives

- To find out the prolonged effect of SOVT Exercise flow resistant therapy (FRT) or straw phonation on acoustic parameters of voice in individuals with normal voice quality.
- To find out the prolonged effect of SOVT Exercise flow resistant therapy (FRT) or straw phonation on glottal parameters of voice in individuals with normal voice quality.

CHAPTER 3

METHOD

Participants

A total of 20 vocally healthy participants, in the age range of 20-30 years, were recruited for the study. To maintain homogeneity and convenience, all the participants enrolled in the present study were females. All the participants were explained the purpose of the study, and prior consent was taken before they participated in the study. All participants were asked not to indulge in excessive caffeine intake, abusive vocal behaviors, and hydrate with at least 8 glasses of water daily.

Inclusion Criteria

- Participants, who had perceptually normal voice quality, based on GRBAS scale (Hirano, 1981). "GRBAS" is an auditory perceptual evaluation tool for voice which stands for "G = Grade or overall severity of dysphonia, R = Roughness, B = Breathiness, A = Aesthenia, and S = Strain voice quality". A 4-point scale was used to rate each perceptual parameter, where "0 = normal, 1 = mild, 2 = moderate, and 3 = severe". Participants with overall score of "0" in the GRBAS scale were selected for participation.

Exclusion Criteria

- Participants, who had upper respiratory tract infection, asthma, or allergic diseases at the time of recording.
- Participants with a history of neurological, speech, language, hearing, or cognitive deficits.
- Professional voice users.

- Participants with long term exposure to alcohol and tobacco consumption (history of withdrawal <5 years).

Tasks

The tasks were recorded twice: once, a day before the introductory and practice session (baseline) and then a day after the conclusion of the 21st session (post training).

All the tasks were recorded individually in a quiet room using an unidirectional microphone positioned at the distance of 10cm from the subject's mouth during the recording in a comfortably seated position. Appropriate instructions were given prior to recording of the tasks.

1. Phonation of the vowel /a/ for about 5 seconds for EGG and acoustic measures

2. Maximum Sustained Phonation of /a/, /s/, /z/ at their comfortable pitch and loudness following a deep inhalation will be elicited twice.

Instruments

The Multi Dimensional Voice Program (MDVP) and Electroglottograph (EGG) softwares of the Computerized Speech Lab (CSL) 4500 model (KAY PENTAX, New Jersey, USA).

Material and Procedure

Initially, a brief summary about the present study along with the consent form were given to the participants. An introductory and practice session followed by 21 continuous daily sessions lasting 15 minutes were carried out. In each session, participants completed the straw phonation exercise protocol as demonstrated in the initial practice session (Table 1).

The first session was monitored, to ensure correct technique and posture. The subjects were asked to place the straw in the mouth with no air leaking around the lips and encouraged to sustain gentle, easy phonation through the straw. They were told to generate sound as if the straw were not present, allowing for adequate airflow and volume. They were provided an external focus such as feeling vibration on the fingertips (which are holding the straw near the lips), and sending the sound through the straw across the room.

In addition to the supervised first session, a detailed video outlining the exercise instructions was circulated amongst the participants. Further, a reference video called "Ingo Titze's tip for tired voices: Grab a straw!" produced by the National Center for Voice and Speech was circulated, as part of the instructions to correctly carry out straw phonation. Participants were asked to keep a record of their daily practice in the log sheet provided to them, and daily reminders were sent through WhatsApp

Electroglottographic signal was recorded for vowel /a/ using Real Time EGG module given by CSL-4500. Recordings were obtained by placing electrodes on either side of the thyroid laminae of the subject's neck and monitoring the signal acquisition using the v-u meter.

Analyses

All the participants were evaluated prior to (practice session) and after completion of the 21 day sessions for acoustic and glottal parameters. Phonation sample were subjected to MDVP analysis and fundamental frequency, intensity and related parameters were extracted.

The following acoustic measures were extracted from the phonation sample using MDVP,

1. Mean Fundamental Frequency (MF0) : Average value of all extracted period to period fundamental frequency values
2. Highest Fundamental Frequency (FHi): Highest fundamental frequency value in phonation.
3. Lowest Fundamental Frequency (FLo): Lowest fundamental frequency value in phonation
4. Standard Deviation of Frequency (STD): Variation of fundamental frequency within the analysed voice sample.
5. Jitter (absolute jitter): It is the evaluation of the period to period variability of pitch period within the analysed voice sample with the voice breaks excluded.
6. Shimmer (in dB): it is the dB of the period to period variability of the peak to peak amplitude within the analysed voice sample with the voice breaks excluded.
7. Noise to harmonic ratio (NHR): It is the average ratio of the inharmonic spectral energy (1500-4500 Hz) in the frequency range to the harmonic spectral energy in the frequency range (70- 4500 Hz).

The following EGG measures were extracted.

1. Contact quotient (CQ): Ratio of the duration of contact phase to total time
2. Contact quotient range (CQr): It indicates the range of vocal folds vibration variability for each token.

Description of the Therapy Program

The materials used for the study were drinking straws of 15-cm long, 4-mm diameter. The same were distributed to all participants and informed to use it regularly for 21 days. The details of the therapy protocol is shown in Table 1.

Table 1

Content of Therapy Program of Straw Phonation Exercises

Sl. No.	Description	Number of trials
1	Sustained phonation of neutral vowel through straw for 10 seconds each with 5 seconds break between trials at comfortable pitch and loudness	10
2	Vocal pitch glides from the low to high to low in a single breath with 5 seconds pause between trials.	10
3	Humming the melodic pattern of the 'Happy Birthday to You' for 15 seconds	10

<u>Statistical Analysis</u>

Descriptive statistics and Paired- t test were used to compare between the baseline and prolonged effects of straw phonation exercises between all the acoustic, aerodynamic and electroglottographic parameters across the group of participants.

CHAPTER 4

RESULTS AND DISCUSSION

The current study aimed at investigating the prolonged effect of one semi occluded vocal tract exercise therapy, straw phonation on normal voice.

The objectives of the study were the following:

- To find out the prolonged effect of SOVT Exercise straw phonation on acoustic parameters of voice in individuals with normal voice quality.
- To find out the prolonged effect of SOVT Exercise straw phonation on glottal parameters of voice in individuals with normal voice quality.

The following statistical tests were carried out to analyze the effects on the acoustic, aerodynamic, and glottal parameters in phononormals across two different time points: before and after 21 days of straw phonation therapy, using 'Statistical Package for Social Sciences' software (SPSS, version 20.0).

1. Shapiro-Wilk test of normality
2. Descriptive statistics
3. Paired samples t-test

Results of Normality

Shapiro Wilk's test of normality was carried out on the data. Three subjects' data was found to have outliers and thus were removed from the data set. When the test of normality was carried out for 17 subjects, the results revealed that the data followed normal distribution (p-value < 0.05).

The results of the current study are discussed under the following sub-headings:

1. Analysis of acoustic parameters before and after therapy
2. Analysis of aerodynamic parameters before and after therapy
3. Analysis of glottal parameters before and after therapy

1. Acoustic Analysis of Phonation Before and After Therapy

A paired samples t-test was carried out to compare the acoustic parameters before and after straw phonation therapy. The mean, standard deviations, and level of significance of all the acoustic parameters measured in the baseline and after straw phonation therapy are given in table 2.

Table 2

Mean, Standard Deviation, t and p values for Acoustic Parameters across 2 Timeframes

Parameter	**Baseline**		**Post therapy**		**Sig.**	**p-value**
	M	SD	M	SD	*t*(16)	
	Fundamental Frequency Related Measures					
MF0 (Hz)	218.22	24.64	223.12	17.70	1.17	0.261
Fhi (Hz)	226.07	21.11	231.20	17.98	1.46	0.164
Flo (Hz)	208.94	23.20	219.08	17.94	2.66*	0.017
STD	2.10	0.61	1.77	0.37	1.94	0.071
	Short and long term frequency perturbation measure					
Jita	36.15	15.88	25.80	9.69	3.04*	0.008
	Short and long term amplitude perturbation measure					
ShdB	0.32	0.10	0.30	0.07	0.95	0.357
	Spectral Measure					
NHR	0.14	0.02	0.13	0.01	1.36	

Note. Hz= Hertz, M=Mean, SD=Standard deviation

*p<0.05

a. Fundamental Frequency Related Measures

The data in Table 1 reveals that the mean fundamental frequency (MF0), highest fundamental frequency (Fhi) and lowest fundamental frequency (Flo) of the subjects were found to be higher after the 21 days of straw phonation therapy. However, Flo between baseline (*M* = 208.94, *SD* = 23.20) and post-therapy recordings (*M* = 219.08, *SD* = 17.94) was found to be statistically significant, $t(16) = 2.66$, $p < 0.05$. This indicates that the subjects low frequency limit increased in all participants post practice and reaching their probable optimal frequency range. Standard deviation of frequency (STD) measured from phonation was found to have lowered after straw phonation therapy, but the difference was not statistically significant. STD is a measure of the standard deviation of period-to-period fundamental frequency values and hence its reduction signifies reduced variation and improved control in the rate of vocal fold vibrations.

These results correlated with several studies. An increase in fundamental frequency values in dysphonic voice reported was by Kaneko, Sugiyama, Mukudai, & Hirano in 2019, after 12 weeks of semi-occluded vocal tract exercises. The findings of the increased fundamental frequency measures are explained by the heightened interaction between the glottis and the supraglottal tract occurring due to phonation into tubes, and the increase in inertive reactance of the vocal tract as a result of its artificial lengthening (Titze, 2006). The resultant increase in vocal tract impedance due to the semi-occlusion appeared to affect the vibrational characteristics of the vocal folds in such a way that the fundamental frequency (F0) approaches the first formant frequency (F1), leading to more efficient voice production, with less vocal effort (Guzman et al., 2013; Story & Titze, 2000). Several other studies have found no significant differences in fundamental frequency parameters before and after straw phonation and the authors had chalked it to acoustic parameters being less sensitive in reflecting precision variation, especially when all participants were from a healthy population without voice disorders (Kang et al., 2018; Ramos & Gama, 2017). Further, Costa, Costa, Oliveira, & Behlau, in 2011 mused that the effects of straw phonation exercises might be a result of cumulative, repeated long-term practice, rather than immediate or short-term, after they found no statistical difference in acoustic parameters in vocally healthy subjects immediately before and after straw phonation exercises. Thus, in the present study though Flo showed a significant increment in the participants, the remaining fundamental frequency parameters may not have shown significant changes due to the short duration of practice and the already normal vocal health of the subjects.

b. Short-Long Term Frequency Perturbation Measure

The absolute jitter (Jita) values recorded in the participants after the 21 days of straw phonation were lower (M = 25.80, SD = 9.69) than those measured at baseline (M = 36.15, SD = 15.88), and the difference was statistically significant, $t(16) = 3.04$, $p < 0.05$ (Table 1). Significant reduction in Jita indicates improved symmetry of rate of vocal fold vibrations confirming the improved F0 related measures.

The significant reduction in absolute jitter values is replicated in Meerschman et al.'s 2019 study in which vocally healthy participants participated in a 3 week-long program for straw phonation exercises and acoustic analysis revealed a significant reduction in frequency perturbation measures. Further, Kaneko et al., in 2019, reported a significant reduction in jitter values in subjects with voice pathology after 6 sessions of straw phonation spread over 12 weeks. These findings can be attributed to the promising physics of a semi-occluded vocal tract gesture, which improves the vibration of vocal folds and assists in its production of acoustic energy via a non-linear feedback mechanism (Kapsner-Smith, Hunter, Kirkham, Cox, 2015 and Titze, 2006). The high supraglottal pressure coupled with the combination of a narrow and elongated vocal tract leads to the best match between source and filter, producing 'pronounced' improvements in voice quality (Gaskill & Quinney, 2012; Titze, 2006). The significant reduction in absolute jitter values in the present study supports the finding that SOVTEs promote a voice quality that is neither breathy nor pressed, a characteristic that many voice therapists would aim for in clinical settings (Rosenberg, 2014).

c. Short-Long Term Amplitude Perturbation Measure

The Shimmer in dB (ShdB) values recorded in the participants after the 21 days of straw phonation are found to be lower (M = 0.30, SD = 0.07) than those measured at baseline (M = 0.32, SD = 0.10). The difference in ShdB values in baseline and post-therapy conditions was however, not statistically significant, t (16) = 0.95, $p > 0.05$. Shimmer reflects phonation stability and indicates the short-wave amplitude in the short run. Though in the current study, shimmer did not show a significant reduction, the decrease in values post straw phonation reflects that with repeated practice, an improvement in these parameters can be expected. A reduction in shimmer is associated with a reduction in breathiness and noise emission, and straw phonation may be useful in creating the same with long-term practice (de Andrade et al., 2019). However, three weeks may be too short a duration to bring about a significant reduction in amplitude perturbation measures in subjects who are already vocally healthy (Meerschman et al., 2019).

d. Spectral Measure

The Noise to Harmonic ratio (NHR) values recorded in the participants after the 21 days of straw phonation are found to be lower (*M*= 0.13, *SD*= 0.01) than those measured at baseline (*M* = 0.14, *SD* = 0.02). The difference in NHR values in baseline and post-therapy conditions was however, not statistically significant, $t\ (16) = 1.36$, $p > 0.05$.

The spectral parameter *Noise to Harmonic Ratio* includes contributions from both perturbations of amplitude and frequency and is correlated with the overall perception of roughness or noise in the signal. Similar to the findings of the current study, Fantini et al. in 2016 reported a non-significant lowering of NHR values in vocally healthy singers after semi-occluded vocal tract exercises, despite a statistically significant lowering of other acoustic perturbation measures. Kang et al. (2019), too, did not report any statistically significant differences in NHR values while studying the lingering effects of straw phonation exercises in vocally healthy participants and recommended repeated practice to achieve optimum effect. As mentioned previously, the non-significant lowering of NHR values may be due to the short duration of practice in the current study, as 3 weeks may be too short to reveal significant changes in acoustic perturbance parameters in phono-normals.

F0 related, Short-Long Term frequency and amplitude perturbation and Spectral measures showed an increment and significance was noted only for a few of these parameters post therapy, strengthening the postulation of better symmetry and coordinated vocal fold vibrations leading to improvement in acoustic measures.

2. Analysis of Aerodynamic Parameters Before and After Therapy

A paired samples t-test was carried out to compare the maximum phonation duration of 'a' (MPD (a)) and maximum frication duration of 's' (MFDs) and 'z' (MFDz), of participants before and after the 21-day straw phonation protocol. The results with the mean, standard deviation, and level of significance of the aerodynamic parameters, at baseline, and post-therapy, are displayed in Table 3.

Table 3

Mean, Standard Deviation, t and p values for Aerodynamic Parameters across 2 Timeframes

Parameter	**Baseline**		**Post-therapy**		**Sig.**	**p value**
	M	SD	M	SD	*t*(16)	
MPD (s)	11.10	3.14	12.52	2.92	2.38*	0.030
MFDs (s)	11.05	3.62	15.71	4.80	4.75*	0.000
MFDz (s)	12.15	4.12	16.17	5.15	3.48*	0.003

Note. MPD= maximum phonation duration, MFDs= maximum frication duration of 's', MFDz= maximum frication duration of 'z', M= Mean, SD= standard deviation.

*$p<0.05$

As can be observed from Table 3, there was a significant increase in the duration of maximum phonation of participants after 21 days of straw phonation, with the mean MPD of participants increasing by 1.5 seconds post-therapy. The maximum frication duration of 's' and 'z' of participants showed a significant increase, too, after straw phonation, with the mean MFD rising by about 4 seconds in the post-therapy measurements.

The tasks of the current study involved doing pitch glides, and pitch variations as part of the 'Happy birthday' humming task. For higher pitches, it is understood that lung pressures, which are much higher than those required for conversational speech, are needed (van der Berg, 1957, Cleveland and Sundberg, 1983). Breath support for the higher lung pressures are achieved through strong muscular contractions in the abdominal and thoracic regions, and the respiratory system is taxed more due to the raised lung pressures (Titze, 1996; Titze, Finnegan, Laukkanen, & Jaiswal, 2002). This repeated taxation of the respiratory system, which leads to an increased vital capacity of the lungs, can help to explain the significantly increased phonation duration, as both maximum phonation time and vital capacity are dependent on the airflow from the lungs (Maslan, Leng, Rees, Blalock, & Butler, 2011). Further, the significant increase in maximum phonation time indicates better respiratory control in the participants after straw phonation (Leite, Christmann, Hoffmann, & Cielo, 2018).

Significant increase in the maximum phonation time after straw phonation thus, indicates encouraging effects of this particular type of SOVTE on the vital capacity of the participants and respiratory control of vocally healthy subjects.

3. Analysis of Glottal Parameters Before and After Therapy

A paired samples t-test was carried out to compare the glottal parameters contact quotient (CQ) and contact quotient range (CQr), of participants before and after the 21 day straw phonation protocol. The results with the mean, standard deviation, and level of significance of the aerodynamic parameters, at baseline, and post-therapy, are displayed in Table 4.

Table 4

Mean, Standard Deviation, t and p values for Glottal Parameters across 2 Timeframes

	Baseline		**Post-therapy**		**Sig.**	**p value**
Parameter	M	SD	M	SD	*t*(16)	
CQ	45.41	5.36	43.33	3.72	1.675	0.113
CQr	10.77	3.27	10.68	3.76	0.71	0.945

Note. CQ = Contact Quotient, CQr = Contact Quotient range, M = Mean, SD = Standard deviation

*p<0.05

As is displayed in Table 4, both values of Contact Quotient and Contact Quotient range decreased in participants after straw phonation therapy; however, the reduction in the same was not of statistical significance.

Artificial lengthening of the vocal tract by using long, narrow tubes increases intraglottal air pressure which tends to separate the vocal folds, which could explain the decrease in contact quotient values, according to Guzman et al., (2013). In his study, he found a 20% decrease in contact quotient values in his subject after 15 minutes of straw phonation. He says phonating into a tube, or a straw occurs involves resistance against airflow, which leads to an increase in supraglottal pressure, thereby leading to a decrease in transglottal air pressure, and an elevation of intraglottal air pressure. The decreasing trend in CQ values might have interesting connotations about straw phonation, helping to reduce vocal fold impact stress (I. Titze, 2006). Again, 21 days may be too short a duration to bring about a significant decrease in glottal parameters like Contact Quotient, in phononormals. Improved mean values of glottal parameters after straw phonation indicate steadier vocal fold vibration with less collision stress in participants.

CHAPTER 5

SUMMARY AND CONCLUSION

The main aim of voice therapy is the production of efficient and economic voice, with minimal stress to laryngeal tissues. Thus, a semi-occluded vocal tract gesture could help in achieving the aforementioned qualities while producing voice, consistently owing to its remarkable coordination in the physical mechanize. It boosts supraglottal pressure and inertive reactance, which enhances the vocal fold vibrations and assists the production of acoustic energy via a non-linear feedback mechanism. Straw phonation is one such category of semi-occluded vocal tract exercises which involves the artificial lengthening of the vocal tract. This particular exercise in unique in that, it creates an additional heightening of supraglottal pressure and inertive reactance, especially if small diameter straws are used. Having been used as a warm up exercise of the vocal apparatus by singers for ages, the straw phonation has gained favour with voice clinicians due to its proven advantages on dysphonic voices: improving auditory perceptual grade or roughness, improving ease of phonation and favourable changes on acoustic parameters too. Additionally, it is easy to execute, levels of difficulty can be easily manipulated, and favours the production of a healthy, effortless voice without fatiguing the respiratory system.

The current study aimed at studying the effects of 21 days of straw phonation on normal voice, across some acoustic, aerodynamic and glottal parameters. For convenience, all 20 subjects were adult female postgraduate students of speech language pathology. Baseline recordings of phonation were measured of all the participants a day before they started the exercises, and post-training recordings were taken a day after they finished. All of the subjects completed 10 minutes of straw phonation for 21 consecutive days, with the drinking straw they were provided. They were instructed on how to perform the exercises, and reminded via messages everyday to do the exercises. Acoustic, aerodynamic and glottal parameters were extracted from baseline as well as post-therapy recordings, using the EGG and MDVP modules from Computerized Speech Lab (CSL) 4500 model (KAY PENTAX, New Jersey, USA). Paired t-test was carried out on the pre and post-therapy values and results revealed a significant increment in Flo, a decrease in absolute jitter values, and an increase in maximum phonation duration in the participants. The outcome of the study lends support to the notion that straw phonation can have beneficial effects on even the normal voice, and could even improve the acoustic and aerodynamic measures.

Clinical Implications of the Study

The current study has the following clinical implications,

- The study supports the idea that straw phonation can be safely incorporated as part of a vocal hygiene program for those with normal voice, and those who are occupational voice users like speech language pathologists, who tend to experience 'tired voice' at the end of the day.
- The study reinforces previous findings about straw phonation improving the quality of voice as evidenced by the significant decrease in absolute jitter values in the participants after 21 days of straw phonation.
- The study adds to the literature concerning the long-term effects of straw phonation on normal voice, and indicates that straw phonation may have significant beneficial effects on several acoustic parameters with prolonged practice.

- The study provides new evidence regarding the effect of straw phonation on the common aerodynamic parameter, maximum phonation time. In addition to its proven advantage of lowering the phonation threshold pressure, straw phonation may also play an important role in increasing vital capacity of lungs, as revealed by the significantly increased durations of /a/, and the fricatives /s/ and /z/ in the participants after 21 days of straw phonation.

Limitations of the Study and Future Directions

- The study employed a small sample size consisting of only 20 female subjects. Replicating the study with a larger randomized sample size and also including males to investigate the gender effects may lend greater support to the findings.
- The same experimenter was involved in assessment and training procedures during the experiment, and which might have caused some degree of experimenter bias to occur.
- Lingering effects of long-term straw phonation practice were not studied, as recordings were done a day after the participants finished 21 days of practice. Follow up assessments done after a few days might have provided insight into the lingering effects of straw phonation, once practice is desisted.

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