EFFECT OF FLUID DENSITY IN WATER RESISTANT STRAW PHONATION EXERCISE ON ACOUSTIC VOICE PARAMETERS IN YOUNG PHONO-NORMAL MALES

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ALL INDIA INSTITUTE OF SPEECH AND HEARING

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SEPTEMBER 2023

CERTIFICATE

This is to certify that this dissertation entitled "**Effect of fluid density in water resistant straw phonation exercise on acoustic voice parameters in young phono-normal males"** is a Bonafide work submitted in part fulfillment for the degree of Master of Science (Speech- Language Pathology) of the student Registration number P01II21S0008. 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
September, 2023

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DECLARATION

This is to certify that this dissertation entitled **"Effect of fluid density in water resistant straw phonation exercise on acoustic voice parameters in young phono-normal males"** is the result of my own study under the guidance of Dr. R. Rajasudhakar, 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.

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CHAPTER-I

INTRODUCTION

The term voice refers to the audible sound that is produced by the larynx and includes characteristics like pitch, quality, loudness, and variability (Aronson et al., 2014). Normal vocal fold and supra-glottic structure and function, normal expiratory flow, and normal nervous system control all contribute to normal phonation. There are five characteristics of normal voice, each associated to function. First, the voice should be audible. Second, the voice needs to be generated in a safe and hygienic way, free from subsequent laryngeal lesions and vocal trauma. Third, the voice must be pleasant and non-distracting. Fourth, the typical voice must be versatile enough to convey emotions. Fifth, the voice should appropriately reflect the speaker's gender and age (Boone et al., 2014).

Any voice that attracts attention, is improper for the speaker's age, gender, or circumstance, or does not satisfy the speaker's social or occupational needs is considered abnormal. When a voice is distinct from the voices of people of a comparable gender, age, and cultural group in terms of quality, pitch, loudness, or flexibility, there is a voice disorder (Aronson et al., 2014). The three conventional categories of voice disorders are: the organic, functional and neurogenic voice disorders. Improper use of the normal voice mechanism results in functional voice disorders (e.g.: ventricular dysphonia, muscle tension dysphonia, etc.). Organic voice disorders are linked to diseases of particular vocal tract structures or to structural abnormalities of the vocal tract (e.g.: vocal cysts, vocal nodules, etc.). The disturbance of the CNS-mediated co-ordination of underlying interconnections results in neurogenic voice disorders (e.g.: vocal fold paralysis, spasmodic dysphonia, etc.)

(Boone et al., 2014). There are both medical and non-medical approaches to treat various voice disorders. Pharmacological and surgical techniques are used in medical management. Behavioral modifications and therapy methods are used in non-medical management. There are several different voice therapy techniques that are used to treat these voice disorders. Voice therapy might be stated as an endeavor for restoring the voice of the patient to a reasonable degree that will suit the patient's social, emotional, and vocational demands (Aronson et al., 2014). There are various voice therapeutic approaches available and some of them are;

- Hygienic voice therapy: It focuses on identifying the behavioral factors that contribute to voice disorders and changing or eradicating these factors (e.g.: Hydration, confidential voice, etc.).
- Symptomatic voice therapy: It involves treating the abnormal vocal symptoms that voice pathologists have found such as breathiness, glottal attacks, low pitch, and so on (e.g.: Abdominal breathing patterns, hard glottal attack, etc.).
- Psychogenic voice therapy: The patient's emotional and psychosocial state, which contributed to and maintained the voice disorder, is the main focus (e.g.: Circumlaryngeal massages, visual biofeedback, etc.).
- Physiologic voice disorder: It depends on direct manipulation of respiration, phonation, and resonance to enhance the co-ordination of laryngeal muscles with the supportive airflow and the proper emphasis of the laryngeal tone (e.g.: Resonant voice therapy, Semi-occluded vocal tract exercises, Vocal function exercises, etc.).
- Eclectic voice therapy: It combines some or all of the voice therapy approaches (Stemple et al., 2020).

Semi-occluded vocal tract exercise (SOVTE) is one of the type of physiologic voice therapy technique. It is indeed a non-invasive voice treatment that improves the vocal economy, efficiency, and loudness (Mills et al., 2018). Semi-occluded vocal tract exercises (SOVTE) have been used in voice therapy clinics since a long time all over the world as a treatment method to lessen the excessive strain on the vocal tract and promote resonant quality of voice (Laukkanen et al., 1996; Titze, 2006). SOVTEs are marked by a decrease in the cross-sectional area of distal vocal tract, which changes the relationship between the glottis impedance and acoustic vocal tract impedance (Story et al., 2000). SOVTE advocate a voice quality that is neither strained nor breathy, an attribute that voice care professionals consider to be ideal (Peterson et al., 1994; Verdolini et al., 1998).

The resistance of SOVTEs to airflow in the vocal tract ranges from high to low. The vocal tract can be made narrow or longer to provide more resistance, or it can be made shorter or wider to create less resistance. From higher to lower resistance, some instances of SOVTEs include humming, phonation with a straw between one's lips, maintaining voiced labio-dental fricatives, voicing during tongue or lip trills, maintaining voiced velar or alveolar nasal consonants, and maintaining vowels with a high tongue position (Titze et al., 2007).

The advantages of SOVTE's on voice are salient, notably for professions that depend on an employee’s clear voice. Those who work in professions where voice overuse is more likely, such as teachers and salespeople may experience more dysphonia incidences (Kooijman et al., 2007). Voice therapy techniques known as SOVTEs have undergone extensive research and received approval for their potential benefits on the voice. A warm-up exercise such as SOVTEs can be used to determine fatigue resistance in singing voice research (Hoch et al., 2018). Following warm-up utilizing occluded ventilation mask SOVTEs, acoustic measures including singing power ratio, shimmer, and jitter, as well as self-assessments such as voice quality and phonatory comfort, have been observed to improve (Fantini et al., 2017). Furthermore, it has been discovered that phonation with a LaxVox tube causes a reduced glottal-to-noise excitation ratio and a rise in fundamental frequency (Fadel et al., 2016).

Straw phonation is the process of making a prolonged vowel while placing a straw between the lips. When using a straw, more intraoral air pressure is produced during phonation (Dargin et al., 2015). Vocalists with typical voices have utilized tube phonation to enhance their clarity, brightness, and sonority. The resonance tube’s distal end can be employed in two different ways: either by dipping it into a cup of water (known as "water resistance therapy") or by being directed as a continuation of the vocal tract from the subject's mouth (Laukkanen et al., 2008). Water-resistance therapy is one of the Fluctuate SOVTE group's sub-exercises. Water-resistance therapy uses phonating with a tube in a bowl or water bottle to control the vocal folds' patterns of closure (Cangi et al., 2022).

Straw phonation is considered to be among the best methods for achieving therapeutic intraoral pressures, than the other SOVTEs (Kang et al., 2019). In comparison to other SOVTEs, straw phonation has a number of exceptional advantages, including ease of accessibility, good efficiency, and controllability (Titze, 2006). Furthermore, compared to other SOVTE instruction, the vocal instruction for straw phonation is considerably simpler (Guzman et al., 2017).

Cangi et al. (2022) investigated the influence of two distinct densities of fluid (mildly thick liquid and water) and two distinct tube submersion depths (10 cm and 2 cm) on electroglottographic and acoustic parameters within the context of SOVTEs. The study was done on 30 females of the age range 20.0- 25.11 years. The study had 4 procedures - P1 (2 cm water), P3 (10 cm water), P2 (2 cm nectar), and P4 (10 cm nectar). A thickener was used with the brand name Thicken-up® for mildly thick liquid in a stable volume (350 mL) and at a stable temperature (25°C). All the procedures were carried out on the same day within a span of 2 hours with 20 minutes break between each procedure. Nasometry and EGG analysis were also carried out. The parameters analysed were contact quotient (CQ), periodicity, fundamental frequency (F0), and nasalance score. First, baseline measures were taken. The task given was sustained /a/ vowel phonation. Then, the straw phonation was performed in 2 cm water for 5 minutes. The subject had to phonate the vowel /u/ in the straw during the exercise. CQ and periodicity were measured during the exercise. Then, post-exercise measurements were taken. A break was given for 20 minutes and then the subject had to perform the same task with the different densities of fluid and submersion depth as mentioned above. The nasalance score generated by the P4 (10 cm nectar) exercise, which gave the most resistance of all procedures, was considerably greater than the nasalance scores produced by the P3 (10 cm water) and P2 (2 cm nectar) activities. This results reveal an entirely distinct framework due to the difference (e.g., tiring) that would arise as a result of the exercises with high resistance in the closure mechanism in the VF region. The fact that all four exercises/tasks were completed in a 2-hour span on the same day would have contributed to the tiredness shown in P4 (10 cm nectar), and the cumulative effects of the workouts might also have contributed to the results. After the exercise procedures, the fundamental frequency values increased. The nasalance score decreased significantly after straw phonation exercise for P3 (10 cm water) and P2 (2 cm nectar). The obtained CQ parameters from the pre-test and post-test (nectar consistency) were found to vary significantly, but during-exercise measurement, parameters did not show any difference. There are studies in the literature that state the difference in during-exercise measurement (Guzman et al., 2015). Hence, this result was inconclusive in the study and it needs to be analysed further. The thickener used in Cangi et al. (2022) study is an expensive one, hence a cheaper alternative could be employed so that people from all socio-economic backgrounds can use the exercise effectively. Study results need caution in generalizing it to male participants, as the study included female participants only. Apart from EGG and Nasometry, routinely used evaluation method is acoustic voice analysis. The previous study did not consider the effect of thin and thick fluids on acoustic voice parameters with water-resistant straw phonation exercise.

Need for the study

The benefits of SOVTEs on the voice are notable. According to recent research, straw phonation is among the most efficient methods among the other SOVTEs, to attain therapeutic intraoral pressures. Many scientists have made various modifications such as submersion of depth (Wistbacka et al., 2018), angle of submersion (Andrade et al., 2016), length (Andrade et al., 2016; Mills et al., 2018), straw's diameter (Wistbacka et al., 2018), and material of straw (Andrade et al., 2016). However, only one study (as mentioned above) by Cangi et al. (2022) which focused on modifying fluid density was found in the literature. The study was done only on 30 female participants in the age range of 20.0- 25.11 years. The evidence regarding the effect of fluid density in water resistance exercise on males is unknown. The parameters analysed in the above-mentioned study were nasalance score, F0, CQ, and periodicity. No study has been done for the measurement of highest F0, lowest F0, jitter, shimmer, and HNR with respect to density change in water resistance exercise. Furthermore, there is a scarcity of research on SOVTEs in the Indian context. Therefore, there is a need to determine the effects of fluid density in water resistance straw phonation exercises in young phono-normal adult male's acoustic parameters of voice.

Aim of the study

The study aimed to examine the immediate effects of two different fluid densities on the acoustic voice parameters using the water resistance exercise in phono-normal adult males.

Objectives of the study

1. To compare the acoustic voice parameters in phono-normal young adults at pre-(baseline), post-2.5 minutes and post-5 minutes of water resistance straw phonation exercise using clear/thin fluid.
2. To compare the acoustic voice parameters in phono-normal young adults at pre-(baseline), post-2.5 minutes and post-5 minutes of water resistance straw phonation exercise using mildly thick fluid.
3. To compare the acoustic voice parameters between the two different types of fluid densities (thin and mildly thick).

CHAPTER- II

REVIEW OF LITERATURE

In voice therapy and training, voice exercises that increase the vocal tract's airflow resistance are frequently utilized. An obstacle to flow is how resistance is defined in terms of physics. The relationship of mean pressure to flow is the mathematical expression of resistance. When there is significant resistance, a reduced flow will be generated at a given potential. As a result, the flow has a negative relationship with resistance and a positive relationship with potential (Baken et al., 2000). Resistance is enhanced with a narrower constriction in the vocal tract. Because of frictional losses, longer and narrower tubes provide higher airflow resistance than shorter and broader ones (Titze, 2002). Resistance rises as a result of hydrostatic pressure, which depends on the water's depth and angle of immersion [Horácˇek et al., 2014 (a); Horácˇek et al., 2014 (b)]. The subglottic pressure (Psub) is elevated, the intra-oral (supra-glottal) pressure is positive and the trans-glottal pressure is reduced when a person is phonating because the airflow resistance at the lips is increased. To initiate and maintain phonation, a subject must produce more Psub as the tube's resistance increases (Titze, 2002). Water bubbles are formed when phonation is made into a tube in water. A varying back pressure is created by the water bubbles, due to which oral pressure (Poral) is modulated and gives a massage-like effect (Enflo et al., 2013; Granquist et al., 2015).

Two ways in which vocal tract resistance might influence voice source performance. Through two different interactions: (1) An interaction between acoustics and aerodynamics (2) A relationship between mechanics and acoustics (Fant et al., 1987; Story et al., 2000). The former alters the structure of the glottal flow pulse as a consequence of the vocal tract's acoustic pressure (Story et al., 2000; Titze, 1988). Because of supra-glottic acoustic pressures, fundamental frequencies (F0s) beneath the first formant cause flow pulse skewing more than the glottal area, suppressing airflow at the time of glottal opening phase and sustaining it at the time of the glottal closing phase. More spectral tilt, higher harmonic strength, higher sound pressure level (SPL), (Rothenberg, 1981; 1983; Titze, 2008), and more resonance in the voice, that is, vibratory feelings in the region around the alveolar ridge, head area, and face's front portion with simple voice production are the results of the glottal flow waveform's increased skewing (Titze, 2001). Because one of the elements affecting voice intensity is the signal of glottal airflow being skewed, the source-filter interaction can boost intensity rather than vibrational amplitude. This stops the vocal fold impact stress from rising (Titze, 2008). The second method that vocal tract resistance might affect glottal source function is through the interaction of mechanics and acoustics between the vocal folds and the pressures in the vocal tract (Bickley et al., 1986; Rothenberg, 1988; Story et al., 2000; Titze, 1988). This occurs when the vocal cord's vibration is impacted by the elevated vocal tract inertance. The inertive reactance specifically reduces the phonation threshold (Titze, 2008). Easy phonation would result from a low phonation threshold pressure.

Studies on SOVTEs are organized under the following sub-headings;

a) SOVTE in phono-normals
b) SOVTE in dysphonia
c) SOVTE in professional voice users
d) SOVTE in children

a. SOVTE in phono-normals

Mills et al. (2018) analysed the influence of tube length on straw phonation exercises in people with normal voices. There were 20 subjects total, including 10 males and 10 women who were college students over the age of 18 years. Three tube lengths with diameters of 2 cm each and length 7.5, 15, and 30 cm Polyvinyl Chloride tubes were considered. Three tube lengths were measured over the course of two weeks on different days. Two tasks were elicited from each tube on the same day v.i.z. short-duration and long-duration. The short-duration task was comprised of 12 trials of vowel /u/ phonation for 5 seconds each, with a 3-second rest in between. The long-duration task consisted of a repetition of 10 short-duration task, with a 30-second rest in between each trial. Oral pressure, aerodynamic resistance (AR), mean airflow (AF), and contact quotient (CQ) measurements were measured for each tube length preceding and following each exercise. The time interval between short and long-duration tasks was 15 minutes. After completing both tasks and following a 15-minute verbal silence, the final measurement was made by the authors. Following completing each activity, participants were asked to assess their degree of discomfort and effort on a scale of 0 to 10, with 10 denoting ‘great effort’ or ‘great discomfort’ and 0 denoting ‘no effort’ or ‘no discomfort’. It has been discovered that short-duration tasks don't have any immediate or lasting consequences. Following a long-duration task, it was reported that AR, CQ, and oral pressure significantly decreased and AF significantly increased. The authors reported that oral pressure, AR, AF, and CQ did not exhibit any notable major effects of tube length. However, AF and CQ showed signs of relevance. Future research should focus on lengthening the time intervals between the SOVTEs, to increase the range of straw length, and to consider more participants.

Using CQ, aerodynamic, and acoustic parameters, Kang et al. (2019) analysed the after-effects of straw phonation within 20 minutes, evaluated the time span of the associated effects after 10 and 5 minutes of straw phonation, as well as measured the optimal amount of time of straw phonation taking into account the after-effects. There were 24 individuals total, seven men and 17 women (mean age: 23.71 $\pm$ 2.24 years). 10 minutes and 5 minutes were chosen as the two straw phonation durations. All participants were entitled to both exercises. Both of the sessions were completed almost at the same timing on two days that followed, separated by a 24-hour period. The data were collected prior to the intervention (baseline), immediately following the intervention (m0), at the five-minute mark (m5), ten-minute mark (m10), fifteen-minute mark (m15), and twenty-minute mark (m20) after straw phonation. The diameter of the straw was 6 mm and the length was 19.5 cm. To ensure proper sound production, the exercises started with a prolonged note and progressively moved on to a sequence of vocal glides. The participants created many accents utilizing abdominal support after the glides, each resulting in a brief change in pitch and loudness. The participants sang certain tunes that could be heard clearly via the straw without causing neck strain. Aerodynamic measurements such as phonation threshold pressure (PTP) and mean airflow rate, EGG measure contact quotient (CQ), MDVP measures F0, noise to harmonic ratio (NHR), shimmer, and, jitter were collected. The PTP required the subjects to say /pi/ into the face mask 15 times as gently as they could. The tasks for EGG and MDVP were to phonate vowel /a/ three times at comfortable loudness and pitch. In acoustic and EGG testing, there were no significant immediate and lasting effects. PTP significantly decreased and mean airflow significantly increased after performing both forms of straw phonation, according to comparisons across measurement circumstances. After straw phonation, significant variations in aerodynamic characteristics were also reported. No significant CQ pattern was noticed during or after straw phonation. After straw phonation exercises, none of the acoustic metrics reported any significant changes. This study has proven that straw phonation of 10 minutes produces the most consistent and optimal results. The fact that the individuals were performing straw phonation for the first time and the lack of a control group both pose limitations to the study.

Shalini conducted a study in 2019 to determine the effects of steady and fluctuating SOVTE on a few acoustic and EGG voice parameters in phono-normals. 20 participants of the age range 18-35 years were considered, out of which 10 were males and 10 were females. The parameters measured were FO, F1, F1-F0, and FO range using PRAAT; OQ, CQ, and SQ using EGG. The straw phonation in the air was considered for the steady SOVTE category and straw phonation in water was considered for the fluctuating SOVTE category. The investigation was done in three stages; phase 1 included baseline measurement. The task was to sustain the phonation of vowel /u/. Phase 2 included the immediate and lingering impact of straw phonation in the air. The tasks were phonation of the vowel /u/, pitch gliding, and humming the melody of the Indian National Anthem. The total duration of the exercise was 5 minutes. Post-exercise immediate effect i.e. (T0) was measured using the same tasks used during the baseline measurement. Post-exercise lingering effects were measured at the 5^{th} (T5), 10^{th} (T10), 15^{th} (T15), and 20^{th} (T20) minute after the completion of the exercise. Phase 3 included the immediate and lingering impact of straw phonation under water which was carried out after a gap of one week. First, the baseline measurement was taken and then the same exercises which were carried out during the straw phonation in air were carried out underwater, and then the immediate and lingering effects were measured. The results indicated that both procedures had beneficial effects on acoustic and EGG parameters of the voice and the effects were reported to last about 15 minutes post-exercise. The study's limitations are small sample size, short exercise time, and aerodynamic and self-perceptual rating scales were not included.

The therapeutic impact of straw phonation versus vocal rest on vocal fatigue were compared and quantified in a study by Kang et al. (2020). The study included 25 healthy participants (15 females and 10 males; average age: 26.1 years). After a vocal loading task of 60-minute (VLT), all participants completed a 10-minute intervention [vocal relaxation (i.e. voice rest) or straw phonation]. For the vocal folds to recover entirely, the two conditions (straw phonation and vocal rest) were carried out with a gap of 48 hours between both procedures. After VLTs, all subjects practised both straw phonation and vocal rest for 10 minutes. By reading aloud for 60 minutes at a level between 75 and 80 dB, the subjects' voices were enhanced. Background noise (ambient and multi-talker babble noise) was played continuously during the process through a calibrated headphones at 75 dB. Every 15 minutes, the individuals were advised to take a break of 30-second and consume 100 mL of water to stay hydrated. The National Centre for Voice and Speech's video "Ingo Titze's Tip for Tired Voices: Grab a Straw!" served as the basis for the instruction given to subjects for the straw phonation condition. The straw's diameter was 5 mm, and its length was 19.5 cm. The tasks for straw phonation were to phonate and pitch glide through the straw. For vocal rest, the participants were instructed to remain silent for a duration of 10 minutes. To monitor the alterations in the voice of the subject at the distinct phases, closed quotient (CQ) of electroglottography (EGG), aerodynamic measurements such as mean airflow and phonation threshold pressure (PTP), and subjective assessments such as laryngeal discomfort (DISC) and current speaking effort level (EFFT) were collected at baseline (t0), after intervention (t2), and after vocal load (t1). The authors found that both conditions (straw phonation and vocal rest) exhibited lower EFFT, PTP, and DISC, and the straw phonation condition had more significant benefits. In addition, compared to vocal rest, mean flow greatly rose and CQ reduced following straw phonation. At the time of straw phonation, the SOVT increases supraglottal pressure and decreases transglottal pressure, which maintains a modest abduction of the vocal folds and lowers CQ. Participants would probably reduce their tendency to overuse their vocal cords as DISC and EFFT decreased post-straw phonation, starting a beneficial cycle of vocal healing. A future investigation into the mechanism behind voice fatigue would require measures of muscle activity and tissue change. An uneven number of female and male participants and the absence of a control group were the study's limitations.

b. SOVTE in dysphonia

Vimal (2016) examined the immediate and prolonged impact of SOVTE in individuals including and excluding voice disorders. 40 participants were divided into two groups. Participants' ages ranged from 20 to 50 years. Group one included 30 participants (15 males and 15 females) with normal voice quality and group two included 10 participants (7 females and 3 males) with mild-moderate dysphonia secondary to hyper-functional voice disorders. Group two was further divided into two groups v.i.z. Group II A included individuals with bilateral vocal nodules (n=6) and group II B included individuals with other hyper-functional voice disorders (n=4). Three phases of the investigation were completed by the author. Phase 1 was the baseline assessment. The individual's task was to sustain the vowel phonation /a/. The parameters measured by the author were F0, F1, F2, and F1-F0 using the PRAAT software; CQ, SQ, and OQ using the EGG and intensity, perturbation measures, noise measures, and tremor measures using the MDVP and Dr. Speech. Phase 2 was to document the immediate effect of SOVTE. All the participants were made to practice the rigid (length: 9cm, width: 2-3cm) and flexible (length: 35cm, diameter: 9mm) straw phonation for 15 minutes. For flexible straw, the subject had to repeat the neutral sustained vowel /a/ for 3 minutes first with a depth of 2-3 cm beneath the water's surface and then with varying depths of the straw in water. Then a melody of the happy birthday was to be sung. For rigid straw, the subject had to sustain the neutral vowel /a/ for three minutes and then sustain the vowel /o/ for another three minutes. Phase 3 was to determine the prolonged effect. In this phase, 10 participants from Group 1, and three from Group 2 were monitored to practice the SOVTE- combined flexible and rigid straw phonation sequence for 10 days regularly for 15 minutes daily.

The results in the normal group showed increased SQ and CQ whereas NNE, Fatr, and OQ were reduced in the immediate post-test condition. CQ increased and SQ and HNR decreased in prolonged post-test condition. The results in the voice disorder group showed increased mean F0 and formants and reduced CQ, SQ, jitter, and shimmer values in the immediate post-test condition. Out of the three subjects considered for prolonged post-test condition, two showed objective changes implying better voice quality. Small sample size, self-perceived rating scales and auditory perceptual tests were not administered which are considered as the limitations of the study.

Guzman et al. (2016) examined the influence of several artificial vocal tract lengthenings (tube phonation in air and water) upon vocal fold adduction and air pressure variables. The study had 45 participants, who were split up into four groups. The first group consisted of people (n = 12; 6 males and 6 females) with a normal voice who had not received voice training. Their average age was 24 years, range: 20–33 years. The average age of the participants in the second group, who had normal voices took vocal training (n = 9; 2 males, 7 females), was 27 years, range: 21-37 years. The third group consisted of individuals with MTD (n = 14; 5 males, 9 females) with an average age of 28 years, range: 23-35 years. The fourth group consisted of individuals with unilateral vocal fold paralysis (n = 10; 8 women, 2 men; age range, 31–56 years). All subjects were required to undergo rigid video stroboscopy prior to the aerodynamic and EGG testing to validate a medical diagnosis. First, baseline recordings for each individual were made. It involved repeating the syllable [pa:] in a habitual, natural-speaking pitch and volume at a pace ranging from 2.5 to 4 syllables per second. Then, in a random order, participants had to select and execute each of the following five semi-occluded vocal tract postures: (1) drinking straw in air (inner diameter: 5 mm; length: 25.8 cm); (2) stirring straw in air (inner diameter: 2.7 mm; length: 10.7 cm); (3) silicon tube in air (inner diameter: 10 mm; length: 55 cm); (4) silicon tube submerged 3 cm below the water surface; and (5) silicon tube submerged 10 cm below the water surface. The task for straw phonation was to phonate through the straws. Subglottic pressure (Psub), fundamental frequency (F0), glottal contact quotient (CQ), trans-glottal pressure (Ptrans), and oral pressure (Poral) were the parameters measured. Psub and Poral were elevated in all semi-occluded postures in comparison to the first condition. The greatest readings for Poral were often obtained when phonation was performed with silicon tube beneath the water's surface. The tube immersed in water for 10 cm had the greatest Poral and Psub measurements. According to the outcome of multivariate linear regression model, the participant groups exhibiting the four distinct voice conditions all exhibited the same air pressure behaviour. Ptrans was greater than the baseline condition in all semi-occluded postures with the exception for the silicon tube in the air, and it differed considerably from the baseline. For all semi-occluded postures, CQ was overall much higher than it was for the baseline. The phonatory tasks using a straw in the air and a tube in 10 cm of water had the highest average CQ values. Due to limited number of participants the variance analysis could not be done, the Finnish glass tube was not used with the other straws and the participants in the groups were not equal in number are the limitations of the study.

Guzman et al. (2017) undertook a study, to analyze the efficiency of tube phonation in the air (TPA) and water-resistant therapy (WRT) for treating patients with behavioural dysphonia. There were 28 participants in the study, of the age range 18 to 50 years. They were assigned randomly to two of the therapy groups by the authors. Group one received water-resistant therapy (WRT) whereas the authors administered tube phonation in air (TPA) to the second group. Each group had 14 subjects, who were allocated evenly among them. Although there were originally 28 individuals registered, only 20 finished the treatment process (10 in each group). Prior to beginning voice treatment, each participant had their voice evaluated using aerodynamic, laryngoscopic, acoustic, electroglottographic, and perceptual methods. Throughout all phonatory tasks, electroglottographic (EGG) and aerodynamic data were concurrently recorded. The authors used two procedures a): "comfortable sustained phonation with EGG" and b): "voice efficiency." In the "comfortable sustained phonation protocol," participants had to utter the sustained vowel /a/. While in "voice efficiency protocol," a flexible and thin plastic tube was put into the mouth of the participants and they had to say /pa/ several times in it and Poral was obtained from it. Phonation Threshold Pressure (PTP) was also acquired through the "voice efficiency protocol." After EGG and aerodynamic assessments, for around 90 seconds, participants read a 242-word, phonetically balanced text. For acoustic analysis, the long-term average spectrum (LTAS) was used. The parameters obtained were glottal resistance, mean glottal airflow, phonation threshold pressure (PTP), contact quotient (CQ), mean subglottic pressure (Psub), the alpha ratio, and L1- L0 i.e. difference of the sound level between F1 and F0 regions. All of the phonetically balanced text's audio samples were recorded, and the auditory perceptual voice quality was examined by three speech-language pathologists with an experience of at least ten years in the voice clinic. Each participant was required to finish the VHI-30's Spanish version. Each participant had to evaluate their voice quality before the acoustic, electroglottographic, and aerodynamic recordings. The perceptual evaluation was carried out using a visual analog scale (100-mm).

Participants attended voice therapy weekly once and a total of eight sessions of voice therapy were attended by the participants. The duration of voice therapy was 30 minutes. Each therapy session consisted of three parts: a) an introduction (3 minutes) wherein the therapist enquired regarding the patient's home training and any voice problems that had arisen the week prior; b) a core (24 minutes) wherein the participants practiced new phonatory tasks; and c) a conclusion (3 minutes) in which the therapist provided the patient with guidelines for home-training. For the activities of the WRT group, five phonatory tasks were executed into a commercially available plastic drinking straw with an inner width of 5 mm and 25.8 cm long. A prolonged vowel-like sound, and singing "happy birthday" song’s melody into the straw, intensity and pitch accents, rising and falling glissandos in an easy vocal range, messa di voce were included in the phonatory exercises. All five phonatory tasks from the exercise group's activities were repeated for the TPA group, but the distal tip of the drinking straw was stabilized in the air. Additionally, lip buzz [ß:] was practised in the initial session for the TPA group to aid the participants in identifying sensations of vibration. The participants of both groups were required to follow all the exercises six-eight times daily at home as part of home training. Post-testing was done precisely one week after voice treatment was finished. The findings seem to support the assumption that WRT might be used to treat patients with functional voice problems. Both groups had a substantial decline in their overall VHI scores following voice treatment. Additionally, the emotional, functional, and physical subscale ratings for the WRT group significantly reduced after therapy. The emotional and functional subscales for the TPA group did not show any changes. WRT had a greater favourable effect than therapy with an air tube in the areas that might be influenced by vocal issues (emotional, physical, and functional). After eight weeks of voice treatment, both groups saw a substantial improvement on the visual analog scale used to measure self-perceived resonant voice quality which showed no difference between the two groups. PTP and Psub significantly dropped for both groups. After an eight-week voice therapy session, there were no noticeable improvements in CQ or EGG. In the pre-post comparison, neither L0–L1 nor the alpha ratio revealed any significant changes. After voice therapy, both groups saw a little decline (more negative values) in both metrics v.i.z. L0- L1 and alpha ratio. Only the TPA group showed pre-post improvements in the auditory-perceptual evaluation. When comparing the pre-and post-conditions, the patients who received WRT did not exhibit any appreciable changes with respect to auditory-perceptual evaluation. The authors speculated that this could be because of the disturbance caused by the water bubbles in auditory monitoring, they recommended further studies to be conducted on this topic. Small sample size and home training was not monitored by the authors using any recording sheet are the limitations of the study.

Meerschman et al. (2019) studied the impact of three SOVT treatment programs— straw phonation, lip trill, and WRT—on voice quality, vocal capabilities, vocal tract pain, and psychosocial effects, in dysphonia patients. This was accomplished through the use of a blocked-randomized sham-controlled experiment, along with a multidimensional voice assessment done by an examiner who was unaware of the groupings. The study comprised 35 patients, with an average age of 21 years (SD = 5.3 years; range = 17-44 years), including 33 women and 2 men. Block randomization was used to divide the participants, separated by age, gender, and whether they were students or employees, into one of four groups: the WRT group (n = 9), the straw phonation group (n = 9), the control group (n = 8), or the lip trill group (n = 9). Before the study's completion, three participants, one from the lip trill group, one from the control group, and one from WRT group withdrew. The straw phonation, WRT, and lip trill groups practiced their respective SOVT tasks twice a week for 30 minutes each over the course of three weeks. The tasks for lip-trill group were practicing lip trill with and without phonation, with loudness and pitch variations, when ‘reading’ sentences and words. The tasks for WRT group were practicing phonation of vowel /u/ and /o/ through the tube submerged in water, using loudness and pitch variations and when ‘reading’ words and sentences. A soft-walled, flexible tube with diameter 10 mm and length 35 cm was used for WRT group. The tasks for the straw phonation group were phonation of vowel /u/ and /o/ through the tube, using loudness and pitch variations and when ‘reading’ sentences and words. A drinking straw of length 21 cm and diameter 5 mm was used for straw phonation group. Participants were asked to practice their individual SOVT exercises for at least five minutes each day at home. The participants in control group had a sham (placebo) therapy during the same period of time, with a weekly session lasting an hour. The measures taken were MDVP, Acoustic Voice Quality Index (AVQI), Maximum Phonation Time (MPT), Dysphonia Severity Index (DSI), highest and lowest frequency from Voice Range Profile (VRP), and Subject's self-report: Voice Handicap Index (VHI), Vocal Tract Discomfort Scale (VTDS), Baseline voice questionnaire, and GRBASI. The voice quality outcomes (DSI, AVQI, and GRBASI) did not show significant time-by-group interactions, indicating any statistically different progression across the four groups. However, the within-group analysis revealed a substantial increased DSI in the groups using the straw phonation and lip trill. The auditory-perceptual evaluation of voice revealed that roughness and grade significantly decreased as a result of straw phonation. On the other hand, WRT and lip trill did have an impact on self-report measures. In the two groups, the psycho-social effect as measured by the VHI considerably decreased. Most participants (n = 6 out of 8) reported improved self-perceived voice quality immediately following the sessions, and three of them continued to report this improvement in the post-test. The authors concluded from the study that WRT was relatively superior to the other two techniques. The variations in intervention frequency and home training assignments among the control group and SOVT groups, the dysphonia type not disclosed by the authors, limited sample size, and the absence of laryngostroboscopic data are the study's shortcomings. There are no long-term follow-up studies available on the three exercises.

c. SOVTE in professional voice users

Using two distinct forms of artificial lengthening on the vocal tract, Guzman et al. (2013) studied the potential training effects on acoustic, aerodynamic, and EGG voice parameters. One male singer with seven years of experience in classical training participated in the study, using various semi-occlusions and tube phonation as vocal warm-up exercises. Analyses of the subglottic pressure, EGG, and CT scan were performed both prior to and afterwards the straw phonation. A glass tube of diameter of 9 mm and length 27 cm and a plastic coffee straw of length 13.7 cm and diameter of 2.5 mm were used in the study. Three tasks have been given for CT analysis: sustained vowel /a/ phonation, a 15-minute workout using both glass tube and coffee straws, and another sustained vowel /a/ phonation. After 15 minutes, the second straw was utilized. For EGG and subglottic analysis, the tasks of the subjects were to produce a series of /pa/ syllable followed by prolonged vowel /a/ phonation, after this five minutes phonation was practiced with a glass tube and then the subjects had to produce a series of /pa/ syllable, prolonged vowel /a/ phonation and the final repetition of /pa/ syllable. After a vocal rest of 15 minutes, the same tasks were repeated with the plastic coffee straw. The parameters measured were Ap/Ae ratio in CT scan, contact quotient (CQ) in EGG, and in LTAS, total SPL, F1 energy, singing power ratio, speaker’s formant energy, and in FFT the F1-F5 and their frequency distances in PRAAT and trans-glottal pressure, oral pressure. The findings demonstrated that even during vowel production following tube and straw phonation, the vocal tract's vertical length increased. After straw phonation, the highest Ap/Ae ratio was shown on the CT scan. According to the study's acoustic findings, straw phonation increased the speaker’s or vocalist’s energy of the formant cluster region. The biggest decline in SPR was seen following straw phonation. A shift in the spectral slope declination and increased spectral prominence in the formant areas of the singer or speaker were found by the authors. The CQ values dropped during the straw and tube phonation as well as thereafter, staying lower than they were before vowel phonation. Straw phonation experienced this transition more than tube phonation. The limitations of the study are that the long-term effects were not studied and it is a single case study hence, generalization of the results is questionable.

Dargin et al. (2015) conducted a study to contrast the EGG and aerodynamic measurements obtained immediately after the completion of the three frequently utilized SOVTEs (lip, tongue trills, and straw phonation). A convenient sample of one soprano and three male tenors attending graduate music programs on the East and Midwest coasts participated in the study. In a quiet clinic room, the participants were seated while the pre-SOVTE- EGG and aerodynamic measurements were obtained. An oral air pressure tube with a tip that rested about 1 cm within the mouth, above the tongue, and behind the central incisors was used to gather the information. It was introduced into the face mask through a port. On the neck, near the thyroid cartilage, the two EGG electrodes were positioned. The aerodynamic signals and the EGG signal were both acquired concurrently, and the PAS programme displayed both. The participants had to produce three trials of the sustained vowel /a/ for 5 seconds for measurement of the EGG parameters. The subjects were instructed to repeatedly say the sound /pa/ while keeping an optimal loudness and pitch for measurement of aerodynamic parameters. Three SOVTEs (lip, tongue trills, and straw phonation) were practiced in random order. The three SOVTEs were practiced each for two minutes without the aerodynamic and EGG instrument in place. Both measures (aerodynamic and EGG) were taken after each SOVTE completion. After completing 20 minutes of the three SOVTEs, a two minutes silence was observed by the subjects and then the final measurement was taken by the authors. The parameters measured were mean expiratory airflow and % of the closed quotient, SPL, aerodynamic resistance, mean airflow during voice, and mean peak air pressure. Irrespective of whichever SOVTE was being performed, the outcome was higher SPL levels and air flow measurements. No consistent pattern of change was seen for two measures, % CQ and oral pressure (as an estimate of sub-glottal pressure), across the three SOVTEs. The findings are consistent with the hypothesis that for singers, SPL, and airflow measurements will probably rise right away after completing any of the three SOVTEs trials. Three of the four subjects had an increase in the % CQ in the carryover condition. Fewer participants, cumulative effects of three exercises examined and the effect of individual SOVTEs not known, and a brief period of SOVTE were the study's limitations.

In order to evaluate the immediate impacts of SOVTEs as vocal warm up on extrinsic laryngeal muscles and vocal tract, Savareh et al. (2021) measured the electrical activity of the laryngeal muscles and the acoustic properties of the voice in singers. 11 male vocalists with an average age of 26.5 ± 4.2 years were the subjects. The three SOVTEs of lip-trill, straw phonation, and humming were chosen. For 20 minutes, the singers engaged in these vocal warm-up activities. Tasks such as prolongation of vowels /a/, /u/ and /i/, and counting from 20 to 30 were used to assess surface electromyography before and after the exercises. Acoustic properties were analysed using Praat software. The task for measurement of acoustic parameters was sustained phonation of vowel /a/ for five seconds. The SOVT exercises included pitch glides from the lowest to the highest note and shifts, ascending/descending 5-note scales on lip trills, pitch glides from the lowest to the highest note and reversals, and ascending/descending 5-note scales on humming. A 15 cm plastic straw with a 3 mm cross-section area was utilized for straw phonation. The exercises for straw phonation include performing accent exercises by creating hills of pitch and loudness 5-7 times while using increased breath support, reading one paragraph (five sentences) through a straw with only emphasizing prosody without articulation, 10 pitch glides from the lowest to the highest pitch and shifts based on the vowel /u/, and singing one short melody with no words through the straw. RMS (Root Mean Square) analysis was used to evaluate electromyography. Additionally, the first formant (F1), fundamental frequency (F0), and the difference between the first formant and the fundamental frequency (F1-F0) were used to do the acoustic evaluation of the vowel /a/. According to the findings of this study, the laryngeal muscle's RMS often reduces following SOVTEs, indicating a reduction in muscular activity. The difference between the first formant and the fundamental frequency (F1-F0), first formant (F1), and the fundamental frequency (F0) all decreased following vocal warming up, according to the results of acoustic assessments. The limitations of the study are the lack of a control group, the small sample size, and only males as participants.

Manjunatha et al. (2022) conducted a study to see if straw phonation might be utilized as a warm-up exercise for speech-language pathologists. All 25 female participants were between the age range of 18 and 25 years, with a mean age of 20.87 ± 1.15 years. Prior to and during the practice of the straw phonation exercise, maximum phonation duration, the perceptual, as well as acoustic characteristics, were evaluated. The vowels /i/, /a/, and /u/ were to be maintained in phonation at a loudness and pitch that the participants felt comfortable with. The acoustic measures analysed were jitter, F0, noise-to-harmonic ratio, shimmer, and soft phonation index using MDVP. Self-perception analysis was conducted using a 4-point rating scale adapted from

Meerschman et al. (2019) study. The straw's inner diameter was 3 mm, and its length was 22.8 cm. Exercises included phonating an extended vowel /a/ into a straw for three repetitions as well as phonating rising and falling glissandos into a straw for three repetitions while maintaining the regular volume and pitch. The exercises each lasted 15 seconds, with a 5-second break in between. The authors found that practising the straw phonation exercises increased overall respiratory phonatory coordination and allowed for the best possible breath control. Authors reported that post-straw phonation, the MPD values enhanced. The mean scores of first formant, F0, fourth formant, second formant, and intensity increased significantly. Most of the participants stated that their post-phonation ratings had significantly increased for "easier and better voice" quality. More research with large sample size and the addition of male SLPs would shed more light on how professional voice users like SLPs would benefit from straw phonation exercises.

In order to determine the immediate impacts of water resistant straw phonation exercises in Carnatic classical vocalists, Devadas et al. undertook research in 2023. Twelve active Carnatic classical singers (10 females and 2 males) with a mean age of 28.25 years, whose daily singing time was of 1-3 hours, and experience ranging from >5 to <15 years were included by the authors. Data were gathered on two distinct days, a day with and without therapy. Using a counterbalancing strategy, the individuals were randomized to either a no-treatment or treatment day. Participants engaged in a vocal loading task on first day (the treatment-free day), singing continuously for an hour while subjected to loud background noise (multi-talker chatter at 65 to 70 dB sound pressure level close to the singer's ear). They sang the ragas, keerthanas, and pillarigeethegalu, the various musical compositions in Carnatic classical singing.

Participants maintained the loudness level of their singing between 65 and 80 dB (monitored by a sound level metre, Ling Wave Software Systems) while singing at their natural pitch (aadharashruthi or base pitch). To be sure that the vocal folds had fully recovered from the impact of the first task's vocal loading, the subjects completed the second vocal loading challenge two days later (after 48 hours). The volunteers did all of the tasks similar to those in the first experiment on the second day of experiment (the treatment day), with the exception of the 10-minute exercises employing straw phonation in water prior to the vocal loading task. The straw used was a plastic drinking straw of length 21.5 cm and a diameter of 0.6 cm. The tasks for straw phonation were to blow in to the straw without voicing, phonation of vowel /u/, and pitch glides.

To evaluate the alterations in the participants' voices, self-perceived voice measurements, EGG, and acoustic measurements were taken at baseline (before vocal loading) and after vocal loading task. The acoustic voice measurements Lowest Fundamental Frequency (Flo; in semitones), Mean Fundamental Frequency (MF0; in semitones), and Highest Fundamental Frequency (FHi; in semitones), were examined using the Praat program from the longest, most consistent vowel /a/ phonation sample (three seconds). Calculations of the semitones were made by comparing them to 1 Hz. The program Multidimensional Voice Programme (MDVP) was used to analyze the Shimmer Percent, Absolute Jitter, Noise to Harmonic Ratio (NHR), Jitter Percent, and Shimmer in dB, from the most stable phonation of vowel /a/ sample (three seconds). Utilising Praat software (version 6.1.12), Smoothened CPP (CPPs) and Cepstral Peak Prominence (CPP) have been extracted from vowel /a/ phonation sample in accordance with the recommended techniques. An Olympus digital voice recorder was used to capture the phonemes /i/, /a/, /u/, /z/, and /s/ for MPD. Using EGG, open quotient (OQ), speed quotient (SQ), and contact quotient (CQ) were computed by the authors.

Perceived Phonatory Effort (PPE), Evaluation of the Ability to Sing Easily (EASE), and the Perceived Vocal Tiredness (PVT), were three self-rated perceptual voice measures used in the study. Comparing several metrics taken prior to and after vocal loading tasks in no-treatment settings (i.e. only vocal loading task) revealed significantly increased PVT, EASE, shimmer percent, and PPE scores as well as a decline in MPD of the vowel /a/. Pre-test and post-test analyses showed a substantial rise in Mean F0, Flo, and FHi, values after straw phonation in water. Measures of self-reported phonatory efficiency (rising PVT and PPE scores) revealed a considerable reduction. Although there was a statistically significant rise in the maximum, mean, and lowest F0 values, this adjustment only affected the mean and maximum F0 values by one semitone. The Lowest F0 was about two semitones. Overall, the study's findings suggested that singing loudly for an hour when exposed to strong background noise might significantly alter a few specific vocal features in Carnatic classical vocalists. The impact of vocal loading on Carnatic classical vocalists were not significantly reduced by straw phonation in water, according to the data. With the exception of MPD of the vowel /a/ and shimmer percent during the no-treatment condition, no statistically noticeable results or tendencies towards statistical significance were reported for the EGG and acoustic measurements. Limitations of the study were unequal number of male and female participants, straw phonation for less duration, and small sample size.

Using a voice self-rating scale and an acoustic evaluation, researchers Yu et al. (2023) investigated the impact of straw phonation exercises on the prevention of voice disorders in telephone customer care workers. 28 individuals participated in this prospective trial. Female telephone customer service agents between the ages of 20 and 50 years and those who used their voices for work on an average of five hours per day and 100 hours per month were required to meet the inclusion requirements. Based on the availability of training time, subjects were non-randomly divided into the control (n = 15) and experimental (n = 13) groups. On the same day as the pre-training voice examination, both the control and experimental groups finished the voice hygiene session. The Chinese Vocal Fatigue Index (CVFI) 9 was included in the pre-training evaluation. The experimental group engaged in a three-week program of straw phonation exercises which included one session of one hour per week. There were minimal vocal hygiene sessions for the control group. Following the training, the experimental group received a voice evaluation, and further evaluations were done one month and three months later. Along with the experimental group, the control group also finished a voice evaluation. The dimension of straw used was 13.5 cm in length and 3 mm in breadth. There were three training sessions, and in the first session, participants were instructed to hold the straw between their lips, allowing only air to pass through it while simultaneously creating a voice sound. Long sounds (10 minutes), five continuous scales (10 minutes), slides up and down (15 minutes), and Chinese characters with various tones (25 minutes) were among the straw phonation exercises in session one. The airflow was maintained with the help of abdominal breath support.

In session two, participants first spent 10 minutes rehearsing the exercises from session one before starting to use straws to produce the prosody related to 2 to 4 Chinese characters. 2 to 4 Chinese characters were created in 25 minutes, and 5 to 8 Chinese characters were then created in the same manner in 25 minutes. Reviewing session 2 took place in session 3 for ten minutes, followed by fifteen minutes of creating prosody without articulation while reading a brief article through a straw. The straw was first used to generate noise and then removed while the air was still flowing, for the second reading. The study’s sentences took 15 minutes to complete with typical articulation.

When the straw was withdrawn to preserve forward focus during this exercise, subjects would perceive that the sound was focused in the face's front portion. The sound might be easily boosted if done appropriately. By reading the study's individual sentences both with and without the straw, the practice is performed several times. Last but not least, during the dialogue stage, the straw was used to generate an initial sound before being withdrawn so that the answer could be given without interruption (20 minutes). For home training, the subjects were asked to carry out the exercises twice a day for 5-10 minutes daily. The voice measurements involved the cepstral peak prominence (CPP), shimmer, jitter, speaking fundamental frequency (SF0), and completing the Chinese Vocal Fatigue Index (CVFI) questionnaire and CAPE-V. The task for analysing jitter and shimmer in MDVP included vowel /a/ phonation for 5 seconds. Six brief sentences were examined using MDVP for SF0, and the third sentence from the CAPE-V Chinese version, which contains continuous vocal consonants /wǒ ai la wei you y u/ was chosen for CPP analysis using the Analysis of Dysphonia in Speech & Voice (ADSV) program. The outcomes showed that in contrast to the control group, the SF0 of participants in the straw phonation exercise program dramatically rose. In terms of jitter, there was no discernible difference between the groups. The experimental group's shimmer decreased significantly whereas the controls exhibited no significant difference. The intra-group study revealed that following training, the experimental group's CPP dramatically rose. During the training period, there weren't discernible variations in the CVFI-1, CVFI-3, and CVFI-2 scores between and among the groups. This demonstrates that voice fatigue was cumulative and did not go right away following the three-week program of straw phonation exercises. However, the experimental group's CVFI-2 and CVFI-1 scores were considerably lower than the control group's during the third month of follow-up indicating that even after three months of training, telephone customer service representatives experiencing physiological symptoms and voice fatigue reported positive improvement. A small sample size, a brief follow-up time, and non-randomized research are the study's drawbacks. Future studies on how straw phonation affects gender-specific voices may employ with male customer service agents.

d. SOVTE in children

In order to ascertain if the duration of straw phonation exercises had an impact on acoustic or auditory perceptual characteristics in children with dysphonia, Ramos et al. conducted a research in 2017. Twenty seven children of the age range 5 to 10 years took part in the study. 25 out of these had vocal fold nodules and two of them had epidermoid cyst of vocal fold. Two groups were made: the control group (CG), which received no therapy, and the experimental group (EG), which received treatment. The participants were placed in both groups one after the other in the same session. The individuals were initially placed in the control group (CG), which included total vocal rest. During the intervention, the participants could play video games but couldn’t talk on the phone. Voice samples were collected before to the CG condition, as well as during the first, third, fifth, and seventh minutes of rest (m1, m3, m5, and m7). Then the participants were subjected to the experimental group (EG) which involved straw phonation in air. Following the demonstration, individuals were instructed to do exercises using a hard plastic straw (1.5 mm in diameter and 8.7 cm in length). The task was to blow air into the straw while producing sound. The duration of both straw phonation and vocal rest were seven minutes each. Voice samples were taken before the straw phonation (m0), as well as after the first, third, fifth, and seventh minutes of exercise (m1, m3, m5, and m7). For analysis of the voice measures, the patients were instructed to count from 1 to 10 and produce the sustained vowels /ɛ/ and /a/ with a comfortable loudness and pitch. Five different trained speech-language pathologists with more than five years of expertise in auditory perceptual analysis of voice were given randomized access to voice samples from the CG and EG.

The Voice's Auditory-Perceptual Analysis Protocol was used to conduct the auditory perceptual analysis of voice. Evaluations of the comparisons listed below were carried out: m0-m1, m0-m3, m0-m5, m0-m7, m5-m7, m1-m3, and m3-m5. The selected parameters for acoustic analysis were jitter, F0, glottal to noise excitation (GNE) ratio, shimmer, and noise (in dB). VoxMetria (CTS.2.6, CTS Informática, Brazil) software was used for the analysis of the acoustic parameters. The comparisons made for auditory perceptual and acoustic evaluation within the group across time points did not show any differences in both CG and EG. After 5 and 3 minutes of straw phonation, the EG's voice quality improved when compared to the CG based on auditory-perceptual evaluation. Vocal breathiness (B), roughness (R), and the grade of dysphonia (G) were the auditory perceptual characteristics that enhanced the most after 5 minutes of straw phonation exercise. Following the third minute of straw phonation, GNE increased and noise reduced in EG when the acoustic characteristics of EG and CG were compared. Children with cysts and vocal fold nodules showed a positive response to straw phonation exercises in terms of auditory-perceptual and acoustic characteristics. According to these findings, the authors recommended that 3-5 minutes of straw phonation would be the suitable duration for children with dysphonia. The limitations of the study are less duration of straw phonation and vocal rest, and both the procedures are carried out in same session so there are possibilities of presence of carry-over effect.

CHAPTER-III

METHOD

Participants

Twenty phono-normal males of the age range 18 to 25 years were included in the study. The participant selection was based on purposive sampling method.

Inclusion criteria

Participants were included based on the perceptual evaluation of voice by using the GRBAS rating scale. Participants whose voice quality was rated as "0" on all parameters of GRBAS rating scale as $G_0R_0B_0A_0S_0$ by an experienced SLP who has more than five years of experience in diagnosing and managing clients with voice disorder were selected.

Exclusion criteria

- The study excluded individuals with a history of upper respiratory infection at the time of recording, ENT pathology, hearing loss, professional voice training in the past, or a history of head and neck surgery.

- Participants were exempted from the study if they reported any history of thyroid-related and hormonal issues.

- Subjects whose score on 'G' was 1 or above or any of the constituent parameters R, B, A, and S were above 1 on the GRBAS scale were exempted from the study.

- Subjects were exempted from the study if they reported any past or present history of smoking habits.

Materials used

Water (thin/ clear fluid), mildly thick fluid (Honey mixed with water - i.e., 10 ml honey mixed with 2 ml water) according to IDDSI framework (IDDSI, 2019), plastic straw (length: 30 cm, diameter: 6 mm), and a PET bottle of 500 mL were used.

Instrumentation

A laptop (ASUS Vivo book 15), Headphones (boat Rockerz 450), and PRAAT software (version: 6116_win32) were used in the study for acoustic analysis.

Procedure

The participants were informed not to mis/overuse the voice, to drink enough water, and refrain from eating anything spicy or caffeinated drinks a day before the data collection. The study's aim and objectives were explained to the participants. Both written and oral consent were obtained from the participants. The experimenter screened the participants using the GRBAS scale (Hirano, 1981). The participants were made to sit in an upright posture on a chair in a noise-free environment and were instructed to sustain the phonation of vowels /i/, /u/, and /a/ in order to carry out the perceptual evaluation.

The study consisted of two tasks;

Task 1: Sustained vowel phonation at a constant intensity and pitch

The subjects were made to sit in an upright posture and were instructed to phonate vowel /a/ in a sustained manner for 5 seconds at constant and comfortable loudness and pitch.

Task 2: Pitch gliding task

The subjects were instructed to phonate vowel /a/ from the comfortable pitch level to an increasingly higher pitch and from the comfortable pitch level to a low-level pitch (i.e. from the comfortable pitch to possible minimum and maximum pitch levels, like a siren) in a slower fashion. Demonstration of the task was provided to the participants.

Measurements were taken at three conditions;

Condition 1: Baseline voice measurement

Condition 2: Post-2.5 minutes straw phonation voice measurement

Condition 3: Post-5 minutes straw phonation voice measurement (immediately after straw phonation)

Condition 1: The baseline voice measurements were taken. The subjects were instructed to perform both tasks as mentioned above. Three trials were recorded for both tasks.

The straw phonation exercises were introduced after the baseline measurement. The total duration of straw phonation was 5 minutes. It was divided into two sets of 2.5 minutes each in order to measure the during-exercise measurement (mid-exercise voice measurement). A PET bottle of 500 mL was used. The submersion level of fluid i.e. water and mildly-thick fluid was 10 cm. Lines were drawn on the bottle to mark the level of fluid and the subjects were instructed to maintain the straw position at the line mark in the PET bottle during phonation exercises. A hole was made in the cap of the bottle to put the straw so that it would be in a stable position. For the straw phonation exercise, a straw with diameter 6 mm and length 30 cm was used for both the water and the mildly thick fluid. The subjects were instructed to maintain an adequate lip seal around the straw so that air should not leak during the exercise. For straw phonation, three exercises were given;

Exercise 1: To sustain the phonation of vowel /u/ for 10 to 12 seconds. Eight trials were practiced with a gap of 2-3 seconds between each trial.

Exercise 2: To count numbers from one to fifteen through the straw. Eight trials were done with a 2-3 seconds gap between each trial.

Exercise 3: To hum a melodic pattern of the "Happy Birthday song" through the straw. Four trials were performed with a 4-5 seconds gap between each trial.

Table 3.1

Number of trials of tasks and its approximate duration

Tasks carried out during straw phonation exercises	**Number of trials and gap between each**	**Duration**
Phonation of /u/ vowel	8 trials with a 2-3 seconds gap between each (Four trials in first 2.5 minutes-set and remaining four trials in the next 2.5 minutes-set).	~1.5 minutes
Counting numbers from one to fifteen	8 trials with a 2-3 seconds gap between each (Four trials in first 2.5 minutes-set and remaining four trials in the next 2.5 minutes-set).	~2.5 minutes
Humming of "Happy Birthday" song	4 trials with a 4-5 seconds gap between each (Two trials in first 2.5 minutes-set and remaining Two trials in the next 2.5 minutes-set).	~1 minute

The five minute exercise regimen of straw phonation is described in Table 3.1. Further, the instructions of each task were written step-by-step on an A3 size paper in English and displayed to the subjects. Participants of this study knows to read and write English language.

Condition 2: After the straw phonation exercise of 2.5 minutes, the voice recording of sustained phonation of vowel /a/ and pitch gliding were taken (Post- 2.5 minutes exercise voice measurement). The subjects had to perform both the tasks mentioned above. Three trials were taken of both tasks. Immediately after the measurement (condition 2), the straw phonation tasks were resumed for another 2.5 minutes during which the subjects had to perform the above-mentioned three exercises that are listed in Table 3.1.

Condition 3: Post- 5 minutes exercise voice recording were done. The subjects were instructed to perform the above-mentioned tasks like sustained vowel /a/ phonation and pitch gliding. Three trials of both tasks were taken. Two different days were considered for data collection. That is, the entire procedure of data collection (from conditions 1 to 3) was done with one type of fluid (clear liquid water) on Day one. After one week, the entire procedure was repeated with mildly thick fluid (Honey mixed with water- 10 ml honey mixed with 2 ml water). That is, 20 participants of the study underwent these exercises twice with one week interval where thin fluid (water) was used on first week followed by mildly-thick fluid (honey mixed with water). The submersion depth considered for the straw in this study was 10 cm of fluid.

Acoustic analysis

PRAAT software (version: 6116_win32) was used to record the above-mentioned two tasks and the samples were saved in .wav format. PRAAT software was utilised to extract the following acoustic parameters from the two tasks;

(a) *Fundamental frequency (F0):* The vibratory rate of the vocal folds is known as the fundamental frequency. It is denoted by F0 and is measured in Hertz (Kent et al., 2002).

(b) *Highest F0:* It is the highest F0 value in phonation or speech. It is denoted by FHi and is measured in Hertz (Kent et al., 2002).

(c) *Lowest F0:* It is the lowest F0 value in phonation or speech. It is denoted by Flo and is measured in Hertz (Kent et al., 2002).

(d) *Jitter:* Frequency perturbation- The variation of the fundamental frequency from one cycle to the next consecutive cycles is called frequency perturbation, often known as jitter (Baken et al., 2000).

(e) *Shimmer*: Measures of amplitude perturbation- The variability in amplitude from one cycle to the next consecutive cycles is known as shimmer (Baken et al., 2000).

(f) *Harmonic to Noise Ratio* (HNR): The mean amplitude of the average wave divided by the mean amplitude of the isolated noise components for the train of waves is known as the harmonics-to-noise (H/N) ratio (Baken et al., 2000).

For measuring the acoustic parameters- Jitter, Fundamental frequency (F0), Harmonic-to-noise ratio (HNR), Shimmer, three trials (of two tasks) were measured and the average of three trials were considered for tabulation and compared between two fluids of different densities. For the acoustic parameters- Highest fundamental frequency (HF0), and Lowest fundamental frequency (LF0), three trials (of two tasks) were measured and the best out of the three trials were considered for tabulation and compared between two fluids of different densities.

A pilot study was conducted on three young phono-normal males before the actual data collection initiated. The tasks were same as given above. With the pilot study it got clear that 5 minutes of straw phonation can be carried out. Some people did not understood how to maintain the position of straw, so considerable amount of trials were given. The instructions for pitch gliding task were not clear to some. Therefore, the task for LF0 and HF0 earlier was to phonate a vowel /a/ from lowest possible pitch to highest possible pitch and vice versa which was changed to phonate vowel /a/ from comfortable pitch to possible lowest and again from comfortable to the possible highest pitch levels after the pilot study.

Statistical analysis

The acoustic parameters measured (F0, HF0, LF0, jitter, shimmer, and HNR) were statistically analysed with the help of SPSS software (version: 26.0) for comparison across conditions and compare between two fluid densities. The distribution of the data was tested using Shapiro Wilk's test of normality. Two way repeated measures ANOVA was performed, where the factors “conditions and density of the fluid” were considered as the “within subject factors” to obtain the main and interaction effects (conditions x density of the fluid). If the main effect was significant, adjusted Bonferroni’s pairwise comparison was performed to test the significance between pairwise conditions {pre- (baseline), post-2.5 minutes, post-5 minutes} and fluid densities (thin and mildly-thick fluid).

CHAPTER-IV

RESULT

The aim of the present study was to investigate the immediate effect of water-resistance straw phonation exercises using two different fluid densities (thin and mildly thick) on acoustic voice parameters in young phono-normal males.

The objectives of the study were

- To compare the acoustic voice parameters in phono-normal young adults at pre-(baseline), post-2.5 minutes, and post- 5 minutes exercise of water resistance straw phonation using clear/thin (e.g. water) and mildly thick fluid (e.g. honey mixed with water).
- To compare the acoustic voice measures between the two different types of fluid densities.

The following statistical tests were performed to analyze the effects on the acoustic parameters across three conditions and two densities of fluid using the software "Statistical Package for Social Sciences (SPSS, Version 26.0)";

1. Shapiro Wilk's test of Normality
2. Descriptive statistics
3. Repeated Measures ANOVA
4. Adjusted Bonferroni Pairwise Comparison

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

1. Results of Normality
2. Results of the descriptive statistics

3. Effect of different densities in water-resistant straw phonation exercise on voice parameters.

1. Results of Normality

Shapiro Wilk's test of normality was performed. The results revealed that the data followed a normal distribution (p-value> 0.05). Hence, parametric test such as two way repeated measures ANOVA was performed to obtain the main effects of fluid densities, conditions and interaction effect (fluid density x conditions). If the main effect was significant, then adjusted Bonferroni pairwise comparison was performed.

2. Results of descriptive statistics

The acoustic voice measures like fundamental frequency, highest F0, lowest F0, jitter, shimmer, and harmonic-to-noise ratio are tabulated and analyzed for descriptive statistics. The mean and standard deviation values for the acoustic voice parameters for the two fluid densities across three conditions are displayed in Table 4.1.

Table 4.1

Mean, and SD values of acoustic voice parameters across three conditions

Parameters	Density of the fluid	Pre-straw phonation (Baseline) (Condition-I)		Post-2.5 minutes of straw phonation (Condition-II)		Post-5 minutes of straw phonation (Condition- III)	
		Mean	SD	Mean	SD	Mean	SD
F0 (Hz)	Thin	130.86	18.75	138.78	27.67	138.97	25.94
	Mildly thick	131.26	18.04	133.74	18.88	134.38	18.59
HF0 (Hz)	Thin	353.31	106.13	335.75	105.76	341.39	97.50
	Mildly thick	350.52	88.57	330.21	97.22	349.34	97.44
LF0 (Hz)	Thin	110.52	23.51	109.96	20.92	113.17	18.30
	Mildly thick	115.03	19.84	112.06	21.39	115.59	20.82
Jitter (%)	Thin	0.36	0.10	0.35	0.15	0.33	0.12
	Mildly thick	0.36	0.12	0.35	0.13	0.35	0.15
Shimmer (%)	Thin	3.39	1.39	3.13	1.34	2.91	1.10
	Mildly thick	3.41	1.19	3.07	1.07	3.24	1.61
HNR	Thin	20.40	2.98	22.08	3.47	22.23	2.90
	Mildly thick	20.36	3.89	21.69	2.77	22.19	4.13

From Table 4.1, the mean values for acoustic parameters like HF0, LF0, jitter, and shimmer reduced after straw phonation exercises post 2.5 minutes for both the fluid densities (thin and mildly-thick fluids). After 2.5 minutes of straw phonation exercises, parameters like F0 and HNR increased for both fluid densities.

After 5 minutes of post straw phonation exercise, parameters like HF0 and LF0 increased for thin fluid (water). On the other hand, parameters like jitter and shimmer values reduced after 5 minutes when compared to post 2.5 minutes condition and there was no change in F0 and HNR values after 5 minutes of post straw phonation exercise when compared to post 2.5 minutes condition for thin fluid.

For mildly-thick fluid (honey mixed with water), post 5 minutes exercise resulted in increased values for F0, HF0, LF0, shimmer, and HNR (except jitter) when compared to 2.5 minutes post straw phonation exercise.

Overall, the acoustic voice parameters such as F0, HF0, and HNR increased from baseline to post 5 minutes of straw phonation exercise for both fluids. Also, parameters like jitter and shimmer values decreased post 5 minutes of straw phonation exercise when compared to baseline condition. As far as LF0 is concerned, for thin fluid, LF0 showed increased values after 5 minutes of straw phonation exercise, but no change in LF0 for mildly-thick (honey mixed with water) fluid when compared to baseline condition.

3. **Effect of different densities in water-resistant straw phonation exercise on voice parameters**

Table 4.2 depicts the results of two way repeated measures ANOVA where the F-value (F) and p-value (p) of main effect and interaction effects of the variables are tabulated.

Table 4.2

Results of two way repeated measures ANOVA

Parameters	**F0 (Hz)**		**HF0 (Hz)**		**LF0 (Hz)**		**Jitter (%)**		**Shimmer (%)**		**HNR (dB)**	
	F	**p**	**F**	**p**	**F**	**p**	**F**	**p**	**F**	**p**	**F**	**p**
Conditions	6.07	0.05*	1.75	0.19	0.89	0.42	1.10	0.34	2.90	0.07	11.88	0.00*
Fluid density	1.87	0.19	0.00	1.00	0.70	0.41	0.08	0.78	0.48	0.50	0.08	0.76
Conditions x fluid type	1.95	0.16	0.38	0.69	0.42	0.67	0.29	0.75	1.25	0.30	0.16	0.86

('*' indicates statistical significance at 0.05 level)

From Table 4.2, it is observed that there was no main effect observed for fluid density and interaction effect for conditions x fluid density. The conditions demonstrated a significant main effect on parameters like F0 ($F= 6.07$, $p < 0.05$) and HNR ($F= 11.88$, $p < 0.05$). Hence, adjusted Bonferroni pairwise comparison was performed to compare between the different conditions {pre- (baseline), post-2.5 minutes, and post-5 minutes}.

1. **Comparison of F0**

The mean and SD values of F0 across three conditions between two fluids are depicted in Figure 4.1.

Figure 4.1

Comparison of F0 across three conditions for two fluid densities

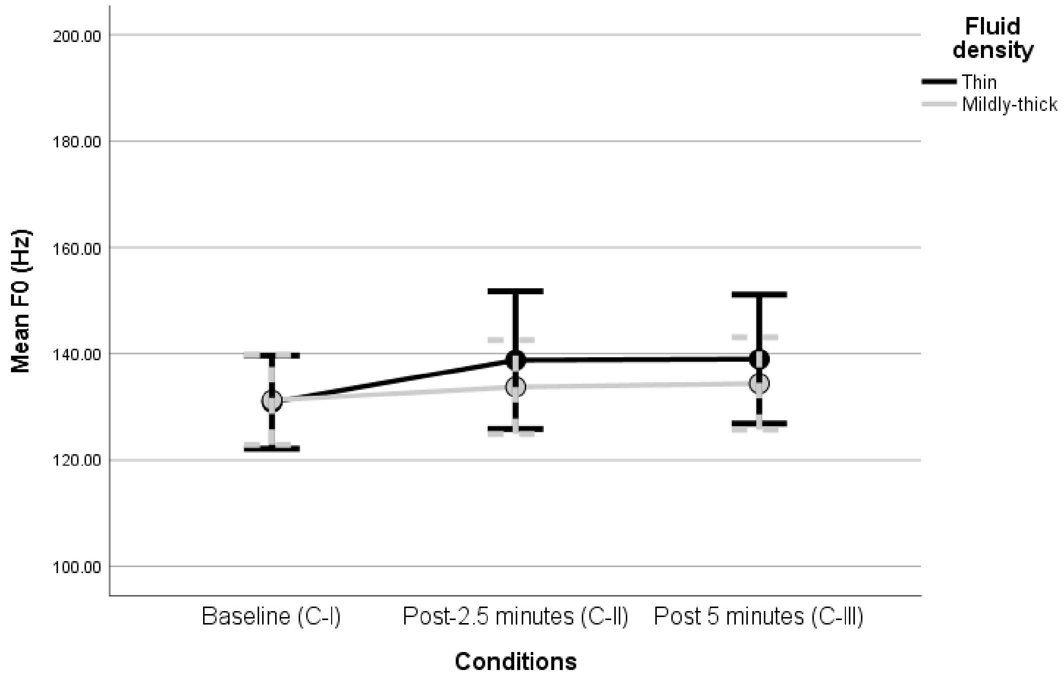

Figure 4.1 revealed that F0 slightly increased immediately after 2.5 minutes of straw phonation (mean: 138.78 Hz for water and 134.38 Hz for mildly-thick fluid) compared to the baseline (mean: 130.86 Hz for water and 131.26 Hz for mildly-thick fluid) and it remained constant after 5 minutes of exercise (mean: 138.98 for water and 133.74 Hz for mildly-thick fluid). Two-way repeated measures ANOVA test was used to calculate the test of significance as the data of F0 was normally distributed. Results of the test revealed that F0 was statistically significant across conditions ($p<0.05$). There was no main effect observed with respect to fluid densities ($p>0.05$). There was no interaction effect observed for conditions and fluid densities ($p>0.05$). Adjusted Bonferroni's pairwise comparison was done and it revealed that conditions one and two (i.e. baseline and post-2.5 minutes) and one and three (i.e. baseline and post-5 minutes) were statistically different. Conditions two and three (i.e. post-2.5 minutes and post-5 minutes) did not show any statistically significant difference. The difference was higher

for thin fluid compared to mildly-thick fluid. Table 4.3 depicts the results of Adjusted Bonferroni pairwise comparison across different conditions for F0.

Table 4.3

Results of adjusted Bonferroni pairwise comparison for F0 across different conditions

Parameter	**Conditions**	**Conditions**	**Mean difference**	**p-value**
F0	(Pre) Baseline	Post-2.5 minutes	-5.20	0.03*
		Post-5 minutes	-5.62	0.04*
	Post-2.5 minutes	Baseline	5.197	0.03*
		Post-5 minutes	-0.42	1.00
	Post-5 minutes	Baseline	5.62	0.04*
		Post-2.5 minutes	0.42	1.00

('*' indicates statistical significance at 0.05 level)

2. **Comparison of HF0**

The mean and SD values of HF0 across three conditions for two fluid densities are depicted in Figure 4.2.

Figure 4.2

Comparison of HF0 across three conditions for two fluid densities

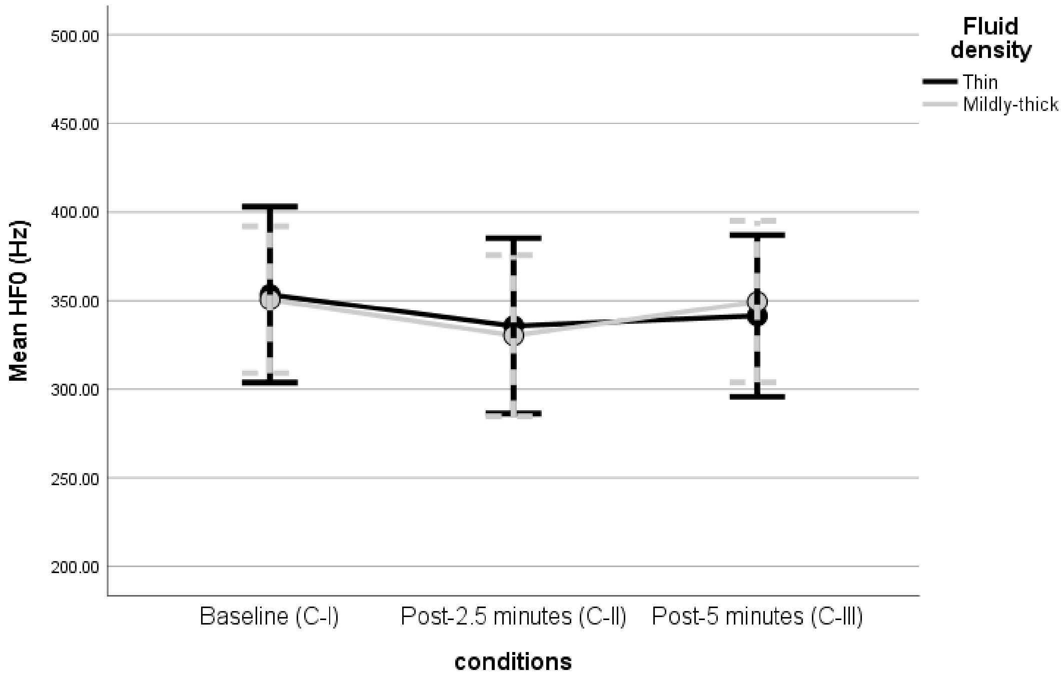

Figure 4.2 revealed that there was a slight reduction in HF0 after 2.5 minutes of straw phonation (mean: 335.75 Hz for thin and 330.21 Hz for mildly-thick fluid) from the baseline (mean: 353.31 Hz for thin and 350.52 Hz for mildly thick fluid), the value increased slightly for mildly-thick fluid after 5 minutes of exercise whereas it remained constant for thin fluid (mean: 341.39 Hz for thin and 349.34 Hz for mildly-thick fluid). The change was more with mildly-thick fluid. Two-way repeated measures ANOVA test was used to calculate the test of significance as the HF0 data was normally distributed. The results of the test revealed that there were no main effects for conditions and fluid density types ($p>0.05$). There was no interaction effect observed for conditions and fluid densities ($p>0.05$) as far as HF0 is concerned.

3. Comparison of LF0

The mean and SD values of LF0 across three conditions for two liquids are depicted in Figure 4.3.

Figure 4.3

Comparison of LF0 across three conditions for two fluid densities

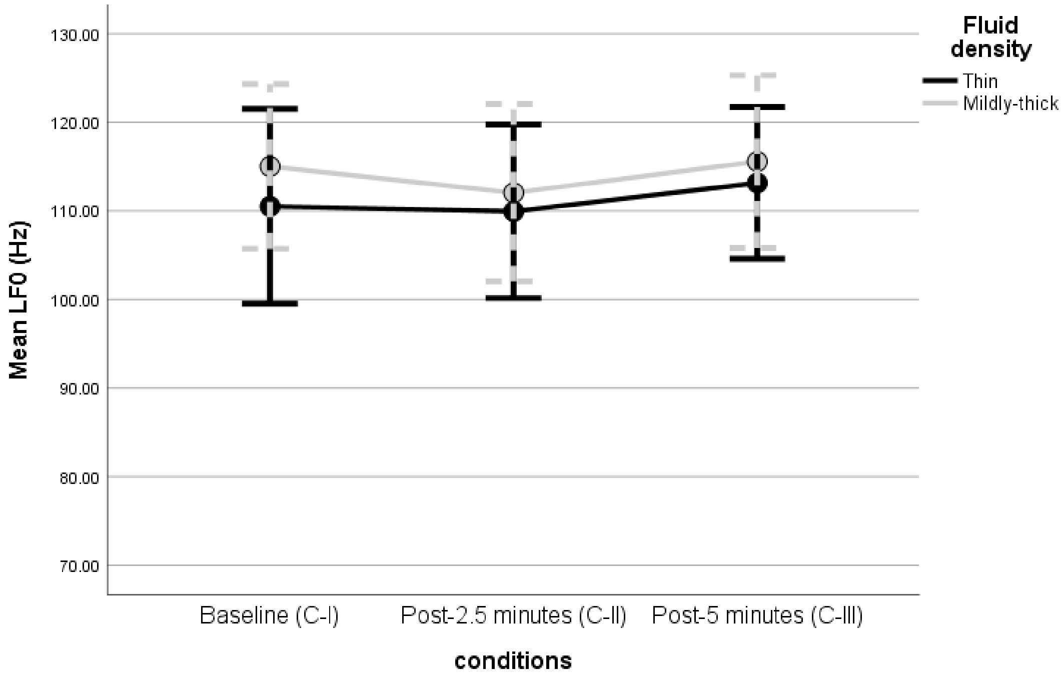

Figure 4.3 revealed that there was a slight reduction in LF0 value after 2.5-minutes of straw phonation (mean: 109.96 Hz for thin and 112.06 Hz for mildly-thick fluid) from the baseline (mean: 110.52 Hz for thin and 115.03 Hz for mildly thick fluid), the value increased slightly after 5 minutes of exercise for both fluid densities (mean: 113.17 Hz for thin and 115.59 Hz for mildly-thick fluid). The change was more with the mildly-thick fluid. Two-way repeated measures ANOVA test was used to calculate the test of significance as the LF0 data was normally distributed. The results of the test revealed that there were no main effects for conditions and two density types ($p>0.05$). There was no interaction effect observed for conditions and fluid densities ($p>0.05$).

The LF0 values remained lower for thin fluid rather than mildly-thick fluid even after post-5 minutes of straw phonation.

4. Comparison of Jitter

The mean and SD values of Jitter across three conditions for two fluids are depicted in Figure 4.4.

Figure 4.4

Comparison of jitter across three conditions for two fluid densities

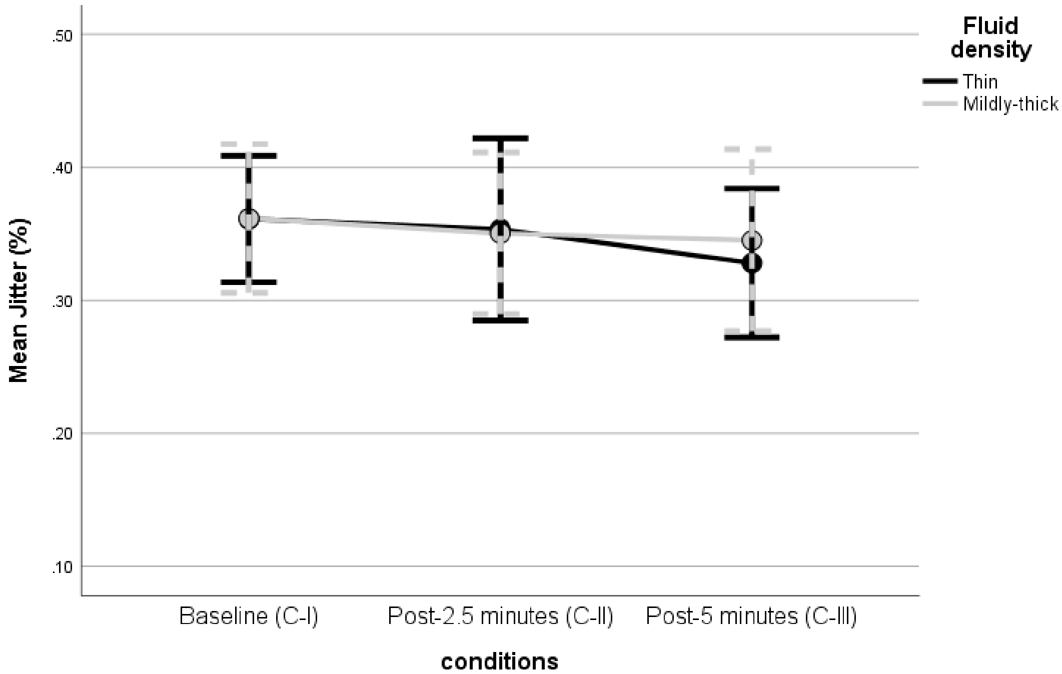

Figure 4.4 revealed that there was a slight reduction in jitter value after 5-minutes of straw phonation (mean: 0.33 for thin and 0.35 for mildly-thick fluid) from the baseline (mean: 0.36 for thin and 0.36 for mildly thick fluid) for thin fluid and it remained constant for mildly-thick fluid. The value remained constant after 2.5 minutes of exercise (mean: 0.35 for thin and 0.35 for mildly thick fluid) for both fluid densities from the baseline. Two-way repeated measures ANOVA test was used to calculate the test of significance as the data of jitter (%) was normally distributed. The results of the

test revealed that there were no main effects for conditions and fluid density types (p>0.05) noted for jitter parameter. There was no interaction effect observed for conditions and fluid densities (p>0.05). The values were reduced but were not statistically significant, and reduction of jitter values was observed relatively more with thin fluid.

5. **Comparison of Shimmer**

The mean and SD values of shimmer across three conditions for two fluids are depicted in Figure 4.5.

Figure 4.5

Comparison of shimmer across three conditions for two fluid densities

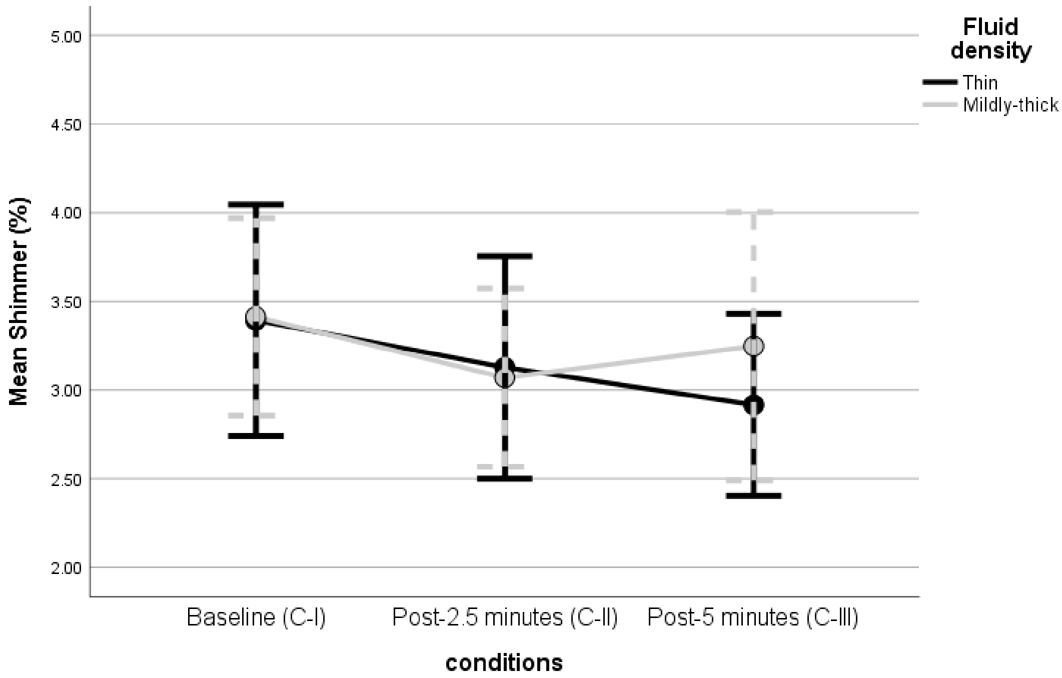

Figure 4.5 revealed that there was a reduction in shimmer value after 2.5 minutes of straw phonation (mean: 3.13 for thin and 3.07 for mildly-thick fluid) from the baseline (mean: 3.39 for thin and 3.41 for mildly thick fluid) for both the fluid densities. The value continued to reduce for thin fluid whereas for mildly-thick fluid,

slight increase was observed after 5 minutes of exercise (mean: 2.92 for thin and increased to 3.25 for mildly thick fluid). Two-way repeated measures ANOVA test was used to calculate the test of significance as the data for shimmer was normally distributed. The results of the test revealed that there were no main effects for conditions and fluid density types (p>0.05). There was no interaction effect observed for conditions and fluid densities (p>0.05) for shimmer parameter.

6. Comparison of HNR

The mean and SD values of HNR across three conditions for two fluids are depicted in Figure 4.6.

Figure 4.6

Comparison of HNR across three conditions for two fluid densities

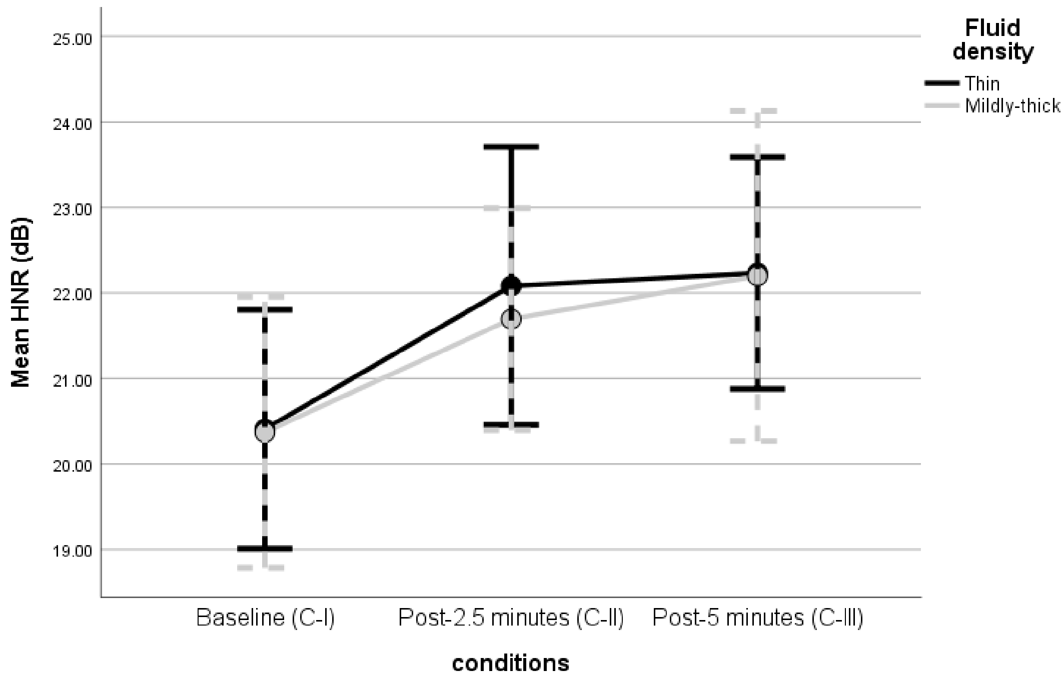

Figure 4.6 revealed that HNR increased immediately after 2.5 minutes of straw phonation (mean: 22.08 dB for water and 21.69 dB for mildly-thick fluid) compared to the baseline (mean: 20.41 dB for water and 20.37 dB for mildly-thick fluid) for both

fluids and it remained constant after 5 minutes of exercise specifically for thin fluid (mean: 22.23 dB for water and 22.20 dB for mildly-thick fluid). Two-way repeated measures ANOVA test was used to calculate the test of significance as it was normally distributed. Results of the test revealed that HNR was statistically significant across conditions ($p<0.05$). There was no main effect observed with respect to fluid type ($p>0.05$). There was no interaction effect observed for conditions and fluid types ($p>0.05$) for HNR parameter. Adjusted Bonferroni's pairwise comparison was done and it revealed that baseline condition differed from post-2.5 minutes and post-5 minutes conditions similar to that of F0. There was no difference between the second and third conditions (post-2.5 and post-5 minutes). The difference was higher for thin fluid compared to mildly-thick fluid. Table 4.4 depicts the results of Bonferroni pairwise comparison across different conditions for HNR.

Table 4.4

Results of adjusted Bonferroni pairwise comparison for HNR across different conditions

Parameter	Conditions	Conditions	Mean difference	p-value
HNR	(Pre) Baseline	Post-2.5 minutes	-1.50	0.00*
		Post-5 minutes	-1.83	0.00*
	Post-2.5 minutes	Baseline	1.50	0.00*
		Post-5 minutes	-0.33	1.00
	Post-5 minutes	Baseline	1.83	0.00*
		Post-2.5 minutes	0.33	1.00

('*' indicates statistical significance at 0.05 level)

CHAPTER-V

DISCUSSION

The study aimed to evaluate the immediate effect of two fluid densities in water-resistant straw phonation exercise on acoustic voice parameters in young phono-normal males. The main and interaction effects of three conditions {pre- (baseline), post-2.5 minutes, and post-5 minutes} and two fluid densities (thin and mildly-thick fluids) on the acoustic voice parameters (F0, HF0, LF0, Jitter, Shimmer, and HNR) were determined using two way repeated measures ANOVA. The result of the analysis revealed that there was no significant main effect of conditions and fluid densities on the parameters HF0, LF0, jitter, and shimmer. There was no interaction effect of conditions and fluid densities on any of the parameters. The conditions exhibited a significant main effect on the parameters F0 and HNR; hence adjusted Bonferroni pairwise comparison was performed to compare the three conditions (pre-, post-2.5 minutes, and post-5 minutes). The results and conclusions drawn from these tests are discussed under the following headings;

Comparison among three conditions and two fluid densities on voice parameters

a) Fundamental frequency (F0 in Hz)

The F0 value slightly increased after 2.5 minutes of straw phonation and it remained constant after 5 minutes of exercise for both the fluids. The difference was higher for thin fluid compared to mildly-thick fluid. Vimal (2016), reported an increment in F0 in prolonged test condition for the combined effect of flexible and rigid straw phonation exercises for normals and voice disorder group. Similarly Shalini (2019) found increased F0 when examining the effects of steady and fluctuating SOVTE in phono-normals. Manjunatha et al. (2022) also found increment in F0 value with straw phonation exercise in speech-language pathologists. Cangi et al. (2022) while determining the effects of varied fluid density in straw phonation exercises, found that the mean values of the F0 parameter obtained after the straw phonation exercises in thin and mildly-thick fluids, the highest value was achieved following the straw phonation in 2 cm nectar i.e. mildly-thick fluid. Reduced stress, reactance, and vocal tract adaptations might be contributing factors to the change in F0 value. The present study findings supports the findings of Vimal (2016), Shalini (2019), and Manjunatha et al. (2022) where they reported increased F0 after straw phonation exercise. The present study findings partially supports the results of Cangi et al. (2022). The present study found increased F0 for both the thin and mildly-thick fluids. But, the increment was higher for thin fluid and not as observed by Cangi et al. (2022) for mildly-thick fluid. However, the frequency parameter is controlled by the cricothyroid muscle, which is active during the straw phonation exercise. Its contractions might cause the F0 to rise (Titze, 2002) post- 2.5 and 5 minutes of straw phonation exercises.

b) Highest fundamental frequency (HF0 in Hz)

HF0 value slightly decreased after 2.5 minutes of straw phonation for both the fluids and it remained constant after 5 minutes of straw phonation for thin fluid and slightly increased for mildly-thick fluid. Devadas et al. (2023) found a significant increase of HF0 values in Carnatic classical vocalists after a vocal loading task (60 minutes) and 10 minutes of straw phonation exercise with plastic drinking straw. This finding was not in accordance with the present study. Further, the HF0 value decreased in a study by Kissel et al. (2023) where they investigated the impact of semi-occluded water resistance ventilation mask technique on vocal outcomes in dysphonic women. The maximum and minimum values of fundamental frequency have been often used to define vocal function (Ma et al., 2007). The rise in HF0 indicates increased range of frequency in the higher registers. The results of the current study indicate that the mean value of HF0 decreased after five minutes of straw phonation exercise with thin fluid and slightly increased with mildly thick fluid. The difference in the findings reported by Devadas et al. (2023) and the present study would be because of methodological differences where the previous study employed Carnatic singers and the present study focused on non-professional voice users with normal voice quality.

c) Lowest fundamental frequency (LF0 in Hz)

There was a slight reduction in LF0 value after 2.5 minutes of straw phonation from the baseline and the value increased slightly after 5 minutes of exercise for both fluid densities. The LF0 values remained lower for thin fluid rather than mildly-thick fluid. Prior to a vocal loading task of 60 minutes, straw phonation exercise of 10 minutes using a plastic drinking straw, Devadas et al. (2023) reported a significant increase in the LF0 values for Carnatic classical vocalists. The current study result is not in agreement with the findings of Devadas et al. (2023). Minimum and maximum fundamental frequency parameters might be used to compare vocal function across numerous groups, including healthy-voiced persons, professional voice users, and dysphonic patients (Heylen et al., 1998). With SOVTEs that lengthen the vocal tract, the low-frequency harmonics benefit from the acoustic inertness of the vocal tract

(Titze, 2018). The reduced values of LF0 in the current study indicate increased dynamic range of voice. Hence, the present study findings revealed that the lower range of phonation frequency can be improved with straw phonation exercise with resistance and the influence of this might be more with thin fluid.

d) Jitter (in %)

The jitter value showed no main or interaction effects of three conditions and between two fluid densities. There was a slight reduction in jitter value after 5 minutes of straw phonation from the baseline for thin fluid and it remained constant for mildly-thick fluid. The value remained constant after 2.5 minutes of exercise for both fluid densities from the baseline. Devadas et al. (2023) reported no change in jitter values in Carnatic classical vocalists after a vocal loading task (60 minutes), prior to straw phonation exercise of 10 minutes with plastic drinking straw. Similar results were found by Manjunatha et al. (2022) in their study of utilizing straw phonation as a warm-up exercise for speech-language pathologists, where the authors found no difference in jitter values after straw phonation. Kang et al. (2019) also found no change in jitter values in their study to analyze the after-effects of straw phonation within 20 minutes, after 5 and 10 minutes of straw phonation. Jitter is a measurement of frequency perturbations within a phonatory sample that varies with vocal fold strain, stiffness, and mass (Robieux et al., 2015). When compared to other acoustic measurements, jitter has shown to be relatively inconsistent (Lortie et al., 2017). The findings of the current study is not in consonance with earlier study findings (Devadas et al. 2023; Manjunatha et al. 2022; and Kang et al. 2019), where they reported no change in jitter parameter after straw phonation exercises. But the present study found reduction in jitter parameter after 5 minutes of straw phonation exercises for both fluids. The reduction was more pronounced for thin fluid than mildly-thick fluid. Reduction from pre- (baseline) to post-5 minutes condition indicate that the vocal folds are vibrating periodically where the cycle to cycle variability is reduced after straw phonation exercises in water. This in turn improves voice quality. However, the reduction of jitter value from baseline to post-5 minutes condition is not statistically significant, which needs to be explored with more sample size.

e) Shimmer (in %)

The shimmer values slightly decreased after 2.5 minutes of straw phonation and remained constant after 5 minutes of straw phonation for both fluids. The value continued to reduce for thin fluid whereas for mildly-thick fluid, slight increase was observed after 5 minutes of exercise. Vimal (2016) found reduced shimmer values in the immediate post-test condition after 15-minute straw phonation with flexible and rigid straws. Similar results were found by Manjunatha et al. (2022) after performing straw phonation with a plastic straw. The shimmer value was found to reduce after straw phonation. Yu et al. (2023) also reported a reduction in shimmer value in telephone customer service staff who underwent three sessions of straw phonation of 60 minutes each. Shimmer varies with glottal resistance and is linked with the presence of breathiness and noise emission; a decrease in shimmer denotes an improvement and results in a voice that requires less effort to produce (Sihvo, 2007). Reduced shimmer suggests that straw phonation exercises stabilize the cycle-to-cycle change in the vocal signal with regard to intensity (Manjunatha et al., 2022). Hence, the results of the current study is in agreement with the findings of Vimal (2016), Manjunatha et al.

(2022), and Yu et al. (2023) who reported decreased shimmer values post-straw phonation exercises, especially with thin fluid.

f) Harmonic to Noise Ratio (HNR in dB)

The HNR value increased after 2.5 minutes of straw phonation and it remained constant after 5 minutes of exercise for both fluids. The difference was higher for thin fluid compared to mildly-thick fluid. Vimal (2016), reported an increment in HNR values in both immediate and prolonged test conditions for the combined effect of flexible and rigid straw phonation exercises for normals and voice disorder group. The HNR is a measurement of the ratio of periodic to non-periodic elements in a spoken speech segment (Murphy et al., 2005). The first component results from the vibration of vocal folds, and the second from glottal noise. The evaluation of the two elements represents the effectiveness of speech, i.e., the higher the flow of air expelled from the lungs, the greater the energy of vibration of vocal folds. A sonorant and harmonic voice is related to a voice that sounds with a high HNR (Boersma et al., 1993). The present study found increased HNR post-5 minutes of straw phonation exercises with both fluids and the effect was more with thin fluid. The increased HNR suggests improved voice quality. The result of the current study supports the findings of Vimal (2016) study where increased HNR parameters reported in both normals and dysphonic group after straw phonation exercises using rigid and flexible straw.

CHAPTER- VI

SUMMARY AND CONCLUSION

Voice is the term used to describe the audible sound that is produced by the larynx and has features like pitch, quality, loudness, and variability. A voice disorder exists when quality, loudness, flexibility, or pitch of a voice differs from voices of individuals in a similar gender, cultural group, and age. Treatment options for different voice disorders include medical (pharmacological), surgical and non-medical (behavioral modifications and voice therapy) measures. Voice disorders other than structural in origin are treated using a variety of voice therapy procedures, in general. Semi-occluded vocal tract exercise (SOVTE) is one of the voice therapy techniques that is commonly used. The key feature of these SOVTE is to reduce the cross-sectional area of distal vocal tract, which changes the relationship between acoustic vocal tract impedance and the glottis impedance. As a consequence, SOVTEs produce a voice quality that is neither strained nor breathy, which is what experts in voice care believe to be a desirable quality. Compared to other SOVTE's, straw phonation is regarded among the best ways to achieve therapeutic intraoral pressure.

The present study aimed to examine the immediate effects of two different fluid densities on the acoustic parameters of voice using the water resistance straw phonation exercise in phono-normal males. The objectives of the study were to compare the acoustic voice parameters in phono-normal young adults at pre- (baseline), post-2.5 minutes, and post-5 minutes of water resistance straw phonation exercise using clear/thin (water) and mildly thick fluid (honey mixed with water); and to compare the voice measures between the two different type of fluid densities. The study comprised of 20 young phono-normal males in the age range of 18-25 years. Two fluid densities were considered for the study, thin (water) and mildly-thick fluid (honey mixed with water). The voice measurements were taken at three conditions: condition 1- Baseline voice measurement; condition 2- Post-2.5 minutes straw phonation voice measurement; condition 3- Post-5 minutes straw phonation voice measurement. A plastic drinking straw of length 30 cm and diameter 6 mm was used for the straw phonation. The straw phonation exercises were done for 5 minutes in total and it included activities such as: sustained phonation of vowel /u/, counting numbers from 1-15, and singing the "happy birthday" song melody through the straw. The 5-minute straw phonation was divided into two sets of 2.5 minutes each. The submersion depth considered for both the fluids was 10 cm. Two days were considered for the data collection, on day one the entire procedure was done with thin fluid (water). Later, after one week, mildly-thick fluid (honey mixed with water) was used. Praat software was used for acoustic voice analysis and the acoustic voice parameters measured were F0, HF0, LF0, jitter, shimmer, and HNR. For measuring the acoustic voice parameters, the participant's task was to phonate the vowel /a/, and glide pitch from comfortable pitch to possible highest and possible lowest pitches.

The results of the present study revealed several points of interests;

First, acoustic voice parameters such as F0 and HNR increased from baseline to post-2.5 minutes of straw phonation exercise and it remained constant after 5 minutes of exercise for both fluids. The frequency parameter is regulated by the cricothyroid muscle, which contracts during the straw phonation exercise. Its contractions may induce the F0 to elevate after 2.5 and 5 minutes of straw phonation exercises. The HNR is a ratio of periodic to non-periodic components in a spoken speech segment. The first component is caused by vocal fold vibration, and the second by glottal noise. The evaluation of these two factors conveys the efficacy of speech, i.e., the higher the flow of air exhaled from the lungs, the larger the energy of vibration of vocal folds. In the current study, increased HNR indicates better voice quality. The present study findings support the findings of Vimal (2016) and Devadas et al. (2023), where they found increased F0 values after water resistant straw phonation exercise. The present study findings supports the findings of Vimal (2016) wherein the HNR values increased after straw phonation in water.

Second, parameters like jitter decreased slightly after 5 minutes of straw phonation from the baseline. Compared to the baseline, jitter remained constant after 2.5 minutes of straw phonation exercise for both fluids. The shimmer and HF0 values decreased post-2.5 minutes of straw phonation exercise when compared to the baseline condition. The shimmer value remained constant for both fluids, but the HF0 value remained constant for thin fluid and slightly increased for mildly thick fluid after 5 minutes of exercise. The reduction in jitter value from pre- (baseline) to post-5 minute condition suggests that the vocal folds are vibrating periodically, and the cycle-to-cycle variability is reduced following straw phonation exercises in thin fluid. This, in turn, improves voice quality. Shimmer changes with glottal resistance and is associated with noise output and breathiness; a decrease in shimmer signifies an improvement and results in a voice that needs less effort to produce. The increase in HF0 suggests a wider frequency range in the upper registers. The current study found that after 5 minutes of straw phonation with thin fluid, the mean value of HF0 declined and slightly rose with thick fluid. This should be investigated further with a greater number of subjects. The present study results of the shimmer parameter is in consonance with the previous studies done by Vimal (2016) and Yu et al. (2023) where they found reduced shimmer values after water resistance straw phonation exercise.

Third, there was a slight reduction in LF0 value after 2.5 minutes of straw phonation from the baseline. The value continued to reduce for thin fluid whereas for mildly-thick fluid, a slight increase was observed after 5 minutes of exercise. The LF0 is lower than the baseline after 5 minutes with thin than the thick fluid. The reduced values of LF0 in the current study indicate increased dynamic range of voice especially in the lower register.

Fourth, though the acoustic voice parameters have shown positive improvement following 5 minutes of straw phonation exercise with thin fluid than mildly thick fluid, but there was no statistical significant difference found between two fluids. This findings suggests that both thin as well as thick fluid has similar effect on measured acoustic voice parameters. Correlation of acoustic voice characteristics with other measures like physiologic or aerodynamic or resonance or perceptual voice parameters can be investigated in the future to examine the effects of different fluid densities on voice employing water resistance straw phonation exercises.

Fifth, Water resistance straw phonation exercise with thin and mildly thick fluids showed greater improvement after 5 minutes of exercise than 2.5 minutes. Longer periods of exercise often enhance the soothing effects on the vocal folds, causing the vocal fold oscillation to accomplish with less effort. Longer exercise duration enhances muscle flexibility, strength, coordination, and endurance of vocal muscles, resulting in better voice quality.

Clinical Implications of the study

- The study's findings shed light on the fact that straw phonation exercise benefits phono-normal males with both thin and mildly thick fluids (two density fluids).
- The study results adds on to the literature regarding the influence of various fluid densities on straw phonation in water resistance exercises in the Indian context.
- The increased acoustic voice parameters like F0, HF0, and HNR and also decreased parameters like jitter and shimmer in the phono-normal male participants after 5 minutes of water-resistant straw phonation exercise suggests improved voice quality. Thus, these exercises with two different fluid densities can be extended to clinical population.

Limitations of the Study and Future Directions

- The study comprised a small sample size consisting of only 20 male participants. Replicating the study with a larger sample size may lend greater support to the findings.
- The straw phonation exercise was examined for a shorter period of time (five minutes). Greater duration of straw phonation can be planned in future.
- Lingering and long-term effects were not studied in the present study. The same can be explored in future studies.

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APPENDIX A

Consent Letter

Effect of fluid density in water-resistant straw phonation exercise on acoustic voice parameters in young phono-normal males

The present study is aimed to determine the effect of two different fluid densities in water resistant straw phonation exercise on acoustic voice parameters in young Indian males. The participants will be asked to perform 'phonation' task through straw in water (thin fluid) for 5 minutes. Similarly, after a week, the same task needs will be performed for 5 minutes under honey thick fluid. Test voice samples will also be collected from the participants before initiation and after termination of water-resistant straw phonation exercise by asking the participants to phonate comfortably vowel /a/ for few seconds in terms of pitch and intensity and gliding the pitch from low to high. The entire procedure to complete straw phonation exercise may take 15 to 20 minutes. Your identity and data will not be shared to any third party and your privacy will be safeguarded.

I have been informed about the aims, objectives and the procedures of the study. The possible risks and benefits of my participation as a human subject in the study are clearly understood by me. I understand that I have the right to refuse participation or withdraw my consent at any time.

I, _______________, the undersigned give my oral and written consent for being participant of this study.

Participant's sign — Researcher's sign

Date: — Date: