IMMEDIATE AND LONG TERM EFFECTS OF LIP TRILL EXERCISE ON VOICE PARAMETERS IN PHONONORMIC INDIVIDUALS

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CERTIFICATE

This is to certify that the dissertation entitled "**Immediate and Long Term Effects of Lip Trill Exercise on Voice Parameters in Phononormic Individuals**" is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) of the student Registration Number: **18SLP010**. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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July 2020

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CERTIFICATE

This is to certify that the dissertation entitled "**Immediate and Long Term Effects of Lip Trill Exercise on Voice Parameters in Phononormic Individuals**" has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that the dissertation entitled "**Immediate and Long Term Effects of Lip Trill Exercise on Voice Parameters in Phononormic Individuals**" is the result of my own study under the guidance of **Dr R. Rajasudhakar,** Reader in Speech Sciences**,** Department of Speech-Language Sciences, All India Institute of Speech and Hearing. Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Register No**: **18SLP010**

July 2020

DEDICATION

I dedicate this work to my thatha, Late. Ranganathan S, because of whom I have chosen this profession.

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பயன்தூக்கார் செய்த உதவி நயன்தூக்கின்
நன்மை கடலின் பெரிது

திருவள்ளுவர்

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter I

Introduction

The human voice is the most beautiful instrument of all, but the most difficult to play

- ***Richard Strauss***

The human voice is produced as a result of vocal fold vibration. The voice can be considered as "clinically normal" based on the five characteristics: (i) adequate loudness, (ii) maintaining proper vocal hygiene, (iii) normal vocal quality, (iv) adequate flexibility and (v) correct representation of the speaker's age and gender. The voice is considered as abnormal or disordered when any one or more of the five characteristics falls above the normal range. Voice disorders occur commonly due to the improper structure and function of the vocal tract (Boone et al., 2014).

Classification of Voice Disorders

Different types of classifications were reported in the literature based on the dichotomy, i.e., organic and functional disorders (Baker et al., 2007). Pannbacker (1984) addressed the types of voice disorders under three main classification (i) based on the aetiology, (ii) based on the perception, and (iii) based on the vocal fold adduction (kinesiologic). The etiological classification was categorized into three subheadings: (i) organic voice disorders due to any anatomical or physiological abnormalities or lesions in the larynx, (ii) psychogenic or functional voice disorders due to the psychological illness or improper vocal behaviours, and (iii) indeterminate cause which includes spastic dysphonia. In Perceptual classification, the voice disorders are classified based on how the listener perceives the voice in terms of pitch, loudness and quality. Kinesiologic classification was based on the movement of the vocal folds, i.e. if the vocal folds hyper adduct, it was termed as hyper-functional dysphonia, and if the vocal folds under adduct, it was termed as hypo-functional dysphonia. Based on the previous literature, Boone et al. (2014) classified the voice disorders into three categories (i) organic voice disorders (ii) neurological voice disorders, and (iii) functional voice disorders.

Voice Therapy Approaches

Voice rehabilitation has given rise to various therapeutic approaches to treat the disordered voice and to improve the normal voice. These approaches were classified as Hygienic, Symptomatic, Psychogenic, Physiologic and Eclectic (Stemple & Hapner, 2018).

Hygienic Voice Therapy

Hygienic voice therapy deals with identifying and eliminating the phono traumatic behaviours such as shouting, throat clearing, inadequate hydration and singing without training to restore the function of vocal folds and to enhance the quality.

Symptomatic Voice Therapy

The symptomatic approach is based on modifying the atypical vocal symptoms such as breathy voice, soft voice, frequent hard glottal attacks, low pitched or high pitched voice etc.

Psychogenic Voice Therapy

Psychogenic voice therapy addresses mainly on the emotional and psychological behaviours of the individuals which had led to voice disorders or which had aggravated the present condition.

Physiologic Voice Therapy

In physiologic voice therapy, direct exercises were given to restore the functions of the laryngeal muscles. It also focuses on working with other subsystems for voice production such as respiratory and supraglottal system.

Eclectic Voice Therapy

Eclectic voice therapy is the combination of any two or more of the above-mentioned therapy approaches.

Semi Occluded Vocal Tract Exercises

The primary objective of voice therapy is to obtain an economical and efficient voice production with minimal muscular effort and loss of energy. Partially occluding the vocal tract while phonation is one of the promising ways to obtain vocal efficiency (Titze, 2006). Semi occluded vocal tract exercises (SOVTE) are commonly applied in voice treatment and training to enhance voice quality. Improvements in relaxed phonation, better voice quality, resonance, adequate respiratory support are some of the positive effects of SOVTE on voice production (Andrade et al., 2014; Kaneko et al., 2019; Rosenberg, 2014). SOVTEs result in a massage-like effect leading to highly relaxed laryngeal muscles and the vocal tract (Andrade et al., 2014; Guzman et al., 2018). Individuals with hyper-functional voice disorders are highly benefited with SOVTE as it relaxes their highly tensed muscles and improves the tone in the facial and laryngeal muscles. This exercise has also been recommended for various other voice pathologies such as paresis, vocal nodules and vocal fatigue (Andrade et al., 2014; Guzman et al., 2013).

In SOVTE, the length of the vocal tract is artificially lengthened, or the epilaryngeal portion is constricted in the anterior region. This narrowing of the epilaryngeal area results in increased inertive reactance which is responsible for lowering the phonation threshold pressure and thereby promoting relaxed phonation (Story et al., 2000; Titze & Story, 1997). Titze and Story (1997) advocated that efficient phonation can be achieved by matching the impedance between the glottal source and the vocal tract. This impedance matching can be achieved by partially obstructing the vocal tract at the labial level or through adjusting the vocal fold adduction and constricting the epilaryngeal area in a combined manner. SOVTE advocates resonant voice production to improve vocal efficiency. The vibration from the facial regions ends in effective energy conversion at the glottal level, which in turn results in better voice quality with minimal stress on the vocal folds (Guzman, 2017).

Based on vibratory sources, SOVTEs are categorized into two groups:

- SOVTEs with one vibratory source which uses vocal folds only, i.e., straw phonation, hand-over-mouth approach, bilabial consonant, and Y-buzz (an exercise which involves the production the semivowel [y] to create the vibration in the facial region which results in increased acoustic pressures in the vocal tract; (Lessac, 1967) and humming.

- SOVTEs with a double vibratory source where a supporting articulator or a device is used in addition to a glottal sound source e.g. Lip trills, tongue trills, combined lip and tongue trill (raspberry) and water-resistant therapy (phonating through the tube immersed in water) (Guzman et al., 2018).

Types of SOVTE

Semi Occluded Vocal Tract Exercise were categorized based on the resistance offered with respect to the air flow in the vocal tract. Higher resistance provides the greater occlusions, while the lower resistance provides the least occlusion in the vocal tract. SOVT based on high to low resistance are listed below:

(i) Phonation through a straw holding with the lips,

(ii) Humming,

(iii) Sustaining a consonant (voiced labiodental fricative),

(iv) Lip and tongue trill,

(v) Sustaining nasal consonants and

(vi) Sustaining high vowels (Rosenberg, 2014)

Lip Trills. Trills are integrated into singing training and vocal warm-ups with multiple intended purposes. Lip or tongue trills promotes inertive reactance in the vocal tract through the constriction at the level of lips or tongue. Lip trills result in increased flow resistance along with variation in time at the lips, which lead to lower intraoral pressure oscillations causing variability in trans glottal pressure. This reduction in the trans glottal pressure results in less force of contact between the vocal folds (Dargin &

Searl, 2015). A literature review on the lip and tongue trill exercises suggested a positive impact on voice quality by balancing the pressure between the supraglottal and subglottal region and by stabilizing the motion of the mucosal wave (de Vasconcelos et al., 2016). Studies have reported reduced closed quotient, followed by lip and tongue trills (Gaskill & Erickson, 2008; Hamdan et al., 2012). Lip and tongue trill are the most widely used SOVT exercises in both voice therapy and linguistics contexts.

Need for the Study

Most of the studies have examined the effect of SOVTEs on electroglottographic, aerodynamic, and instrumental acoustic measurements and reported that there is a larger variability noticed between and within individuals in terms of the effect of SOVTE (Dargin et al., 2015; Guzman et al., 2015). However, only few studies (Brockmann et al., 2019; Meerschman et al., 2019) have reported the effect of SOVTE on clinically applicable and multidimensional measurements such as voice range profile (VRP), Dysphonia Severity Index (DSI) and maximum phonation time which is quite sensitive to indicate the immediate effect of SOVTE (Meershman et al., 2019).

Even though there are many studies on secondary source of vibration which has reported the immediate effect of SOVTEs (Andrade et al., 2014; Brockmann et al., 2019; Dargin et al., 2015; Guzman et al., 2015; Meerschman et al., 2019), only two studies till date have compared the immediate and the long term effect of SOVTE in vocally healthy individuals and dysphonic population (Guzman et al., 2018; Vimal, 2016). Comparison of the immediate and long term impact of SOVTE can help in calculating how much training is required to transfer the immediate effects to optimal vocal function, which aids in selecting a suitable treatment regimen.

There was a similar study that had investigated the Immediate Lip Trill Effects on Voice Range Profile, Jitter, Maximum Phonation Time, and Dysphonia Severity Index in 25 phononormic females (Brockmann et al., 2019). However, this study was done only in the female population, so the results cannot be generalized to the male population. Hence, there is a need to investigate the lip trill effects in both males and females to generalize the results.

Further, there is a dearth of literature on investigating the effect of SOVTEs in the Indian context. There are only a few unpublished data available on investigating the effects of SOVT in the Indian population (Shalini, 2019; Vimal, 2016).

With reference to the above issues, the present study was taken up to investigate the immediate and long term effect of a SOVTE, lip trills in vocally healthy individuals on Speaking fundamental frequency, Voice Range Profile and Dysphonia Severity Index.

Aim

The present study is aimed to examine the immediate and long term effect of a semi occluded vocal tract exercise with a secondary source of vibration, lip trills on voice parameters in Phononormic individuals

Objectives

- To investigate the immediate effect of lip trill exercise in vocally healthy individuals.
- To investigate the long term effect of lip trill exercise after a week of home training in vocally healthy individuals.

- To investigate the gender differences (if any) in the immediate as well as long term effect of lip trill exercises in vocally healthy individuals.

Chapter II

Review of Literature

SOVTEs are generally characterized by a narrowing of the surface region in the anterior portion of the vocal tract. The decrease in the distal area can be accomplished with the help of nostrils, lips, tongue or other external devices such as tube, straw and hands over the mouth during phonation. The narrowing of the surface area of the vocal tract during SOVTE leads to greater acoustic impedance and larger supra-glottal air pressure which matches with impedance and pressure in the subglottal area resulting in a better phonation (Brockmann-Bauser et al., 2019).

Ayers (1998) explained the principle of SOVTEs using an analogy of brass instrument playing. While playing a brass instrument, despite the sudden change in pressure, lip vibrates without much collision, in a simple oscillatory motion. In the same manner, vocal tract actively participates in the production of energy by converting more aerodynamic into acoustic energy, rather than just as a filtering mechanism to selectively filter partials of the spectral source in a passive manner.

Maximum interaction between the supraglottal tract and the glottis can be achieved through SOVT Exercise. Nonlinear interaction can happen between the supraglottal or subglottal tract and the glottal area. The modal register is facilitated by the subglottal interaction, where the distal portion of the vocal fold attributes to the increased vibration. On the other hand, supraglottal interaction facilitates the mixed register, where the proximal portion of the vocal fold attributes to the vibration (Titze, 2006).

During SOVTEs, the intraoral pressure is increased behind the occlusion in the vocal tract, and if the narrowing happens near the mouth, the first formant frequency (F1) is lowered (Bickley & Stevens, 1991). Addition of an external tube can maximize the inertive reactance and further lowers the F1, due to increased length (Story et al., 2000). With these semi occlusions, the supraglottal pressure can have a larger influence on glottal airflow and transglottal pressure (Titze, 2002). Maximum flow declination rate (MFDR) in the glottal area is increased by creating the feedback nonlinearity through building proper relations between transglottal and supraglottal pressure. Thus, SOVTE relies on non-linear source filter interaction in the production of acoustic energy through a feedback mechanism by creating a heightened supra glottal pressure and increased inertive reactance, which facilitates the vibrations in the vocal folds. (Guzman et al., 2017; Kapsner-Smith et al., 2015; Titze, 2006).

SOVTEs are categorized into SOVTEs with a single source and SOVTEs with a dual-source depending on the vibration sources. Several studies have been investigated in recent years on SOVTE and it have confirmed both the efficacy and underlying rationale behind SOVTEs. Miller and Schutte (1991) justified that a secondary vibratory source at the anterior portion of the vocal tract creates a varying oral pressure (P_{oral}) effect on vocal fold oscillations. This secondary source effect was also associated with the massage-like effect and efficient blood flow due to tissue vibrations in the vocal tract.

SOVTEs in Phononormals

Andrade et al. (2014) investigated the impact of the secondary vibratory source using different SOVTEs on vocal fold pattern in 23 vocally healthy individuals using acoustic and electroglottographic measures. Sustaining a vowel /a/ at their habitual pitch and loudness was taken as a control exercise. All participants were instructed to sustain a vowel at their habitual pitch and loudness as a baseline and then they were instructed to perform one of the seven exercises which were randomly chosen. The seven SOVTEs include straw phonation (straw with 12.5 cm length and 4mm diameter), LaxVox30 (a silicone tube with 25 cm length and 9 mm diameter), lip trills, tongue-trills, hand-over mouth, humming, and hand-over mouth and tongue trill combined together. These SOVTEs were initially demonstrated by the speech-language pathologist to the participants and they were asked to imitate the speech-language pathologist. The acoustic parameters considered were: (i) fundamental frequency (F0), (ii) fundamental frequency range (F0r), and (iii) the difference between F1 and F0 (F1−F0). The electroglottographic parameters considered were: (i) contact quotient (CQ), and (ii) contact quotient range (CQr). The results showed increased mean F0 for all the seven SOVTEs when compared to the comfortable phonation but it was not statistically significant. The electroglottographic analysis revealed that SOVTEs with a secondary vibratory source such as LaxVox, lip and tongue trills and tongue trills and hand-over-mouth combined together had resulted in a significantly larger range of CQ and F0r. Authors attributed these findings to the greater variations in the adductory and abductory phases of the vocal folds which were due to altered intraoral pressure and resulted in a stronger massage effect. And also, Andrade et al. found that the mean F1-F0 difference was statistically decreased in SOVTEs when compared to the control exercise which indicated an easier phonation. This study was the initial one to statistically affirm the significant change in the vocal fold behaviour due to the secondary vibratory source in the vocal tract. The limitations of the study include: (1) all the seven SOVTEs were done in one therapy session which might have caused carry over effect; (2) The time interval between the introduction of different SOVTE and at what period the outcome measures were assessed was not stated clearly; and (3) Therapy procedure was not explained in the study.

Brockmann-Bauser et al. (2019) examined the immediate impact of lip trill exercise on acoustic and aerodynamic outcome measures. This study consists of 25 phononormal female participants in the age range of 19-58 years. All the individuals who participated in the study were reported to be phononormals with normal speech, language, and cognitive abilities and without any associated disorders. These participants were instructed to perform lip trill exercise which consisted of 11 steps. The total duration of the exercise was 3 minutes. The 11 steps included in the exercise are sustained phonation at habitual frequency; short small frequency variation; long small frequency variation; short large frequency variation; long large variation in the pitch; pitch upward gliding; pitch upward and downward gliding; pitch downward and upward gliding; pitch gliding upwards and downwards with increasing fundamental frequency range; pitch gliding downwards with the increasing fundamental frequency range and increasing loudness. Each lip trill step was demonstrated by the researcher and then it was imitated by the participants. The participants were assessed before and immediately after the lip trill exercise. The outcome parameters considered in the study were counting fundamental frequency (counting F0); voice range profile; Jitter; maximum phonation time (MPT) and dysphonia severity index (DSI). For calculating counting F0, the participants were instructed to count from 21 to 25 at their comfortable pitch and loudness. For calculating voice range profile, the participants were asked to sustain a syllable /la/ in their softest voice from their optimal voice range to their lowest pitch; then from their comfortable voice range to their highest pitch. Finally, the participants were asked to repeat the same task at their loudest voice. Jitter and MPT were calculated based on the phonation. Results showed a significant increase in the speaking F0 and total singing F0 range. Bauser et al. attributed this increase in F0 and singing F0 range to increased vocal fold tone and optimized voice function. The maximum sound pressure level and intensity range were also reported to be statistically significant. Bauser et al. stated that the increase in F0 and SPL were associated with increased intrinsic vocal fold tonus and higher subglottal pressure as a result of exercise. Authors also reported that lip trill is an efficient exercise to immediately improve vocal performance and can be used as a therapy approach.

Shalini (2019) investigated the immediate, lingering and gender effects of steady and fluctuating SOVTEs on acoustic and electroglottographic parameters in 20 phononormals with the age range between 18 to 35 years. The study was carried out in three phases. Phase I was considered as a baseline where the participants were asked to phonate vowel /u/. In phase II, the participants were asked to phonate through the straw by placing the one end between the lips and the other end into the air (exercise I). The entire task duration was 5 minutes which consisted of sustained phonation; pitch glides and humming the melody of the Indian National Anthem. In phase III, the participants were asked to phonate vowel /u/. At phase I and III, both acoustic and electroglottographic measurements were done. In phase III, tasks, post exercise measurements were done at four different levels: immediately after the exercise; at 5th minute; at 10th minute; at 15th minute and at 20th minute for analyzing lingering effect. The participants were called again after a week for the second SOVT exercise, i.e., phonating through the straw by placing one end between the lips and the other end submerged in water (exercise 2) where the 5 minutes SOVTE steps were similar like exercise I. Both the baseline (phase I) and post-exercise (Phase III) measurements were reported to be similar in the study. The outcome measures were acoustic parameters such as Fundamental frequency (F0), Range of Fundamental frequency (F0r) and frequency difference between first formant frequency and the fundamental frequency (F1-F0) and electroglottographic parameters such as Contact Quotient (CQ), Range of Contact Quotient (CQr) and Speed Quotient (SQ). The results indicated that there was a significant increment in the F0r and SQ immediately post exercise for both the exercises. The author has reported that the increment gradually returned to baseline at 20 minutes post exercise. It has been stated that the lingering effects of SOVT were present till 15 minutes post exercise. The author also found that there was a significant increase in F1-F0 and SQ values for males compared to females while there was significant decrement in F0 value, F0r, CQ and CQr for males compared to females. The author concluded that both SOVTEs provided beneficial effects on the electroglottographic and acoustic parameters of the voice which were also found to last about 15 minutes post exercise. The limitations stated by the author in this study were (i) lesser sample size (ii) the time duration of the exercises were short (iii) self-perceptual analysis and aerodynamic measurements were not included (iii) the same experimenter was present in baseline measurement and training phase which might have led to experimenter bias (iv) control group was not included.

SOVTEs in Dysphonic Population

de Vasconcelos et al. (2017) investigated the effect of lip trill and tongue trill exercise before and after therapy in the subjects with vocal polyps. The study consisted of 10 subjects who had vocal polyps and were divided into two groups regardless of the polyp size and type: (i) treatment group and (ii) control group. Two male and three female subjects within the age range of 30 to 60 years were considered in each age group. The control group consisted of subjects who had chosen surgery as a treatment option whereas the treatment group had chosen voice therapy as a treatment option. The assessment protocol includes: (i) laryngoscopic examination; (ii) perceptual voice evaluation; (iii) acoustic voice evaluation; (iii) vocal habit and symptom questionnaire and (iv) vocal self-assessment. The acoustic voice parameters considered were (i) jitter; (ii) shimmer; (iii) the proportion of glottal signal/noise excitation (GNE) and (iv) phonatory deviation diagram (PDD). Sustained phonation was the task given for baseline measurement and PDD was extracted with respect to the quadrant location of phonation and with respect to the density and spread of the emission points using VoxMetria program. For perceptual assessment, Consensus Auditory- Perceptual Evaluation of voice was carried out and the overall severity level was analyzed. For self-vocal assessment, questionnaire consisted of vocal habits and symptoms was administered using a visual analog scale. All participants have undergone baseline evaluation, and reevaluation was done after 3 months. In the therapy phase, all participants were asked to perform either lip trill or tongue trill exercise for 3 minutes. The therapy protocol consisted of four levels: (i) sustained phonation using lip trill or tongue with voicing; (ii) pitch variations; (iii) varying the pitch between two frequencies resembling a siren and (iv) humming the tune of "Happy Birthday To You" using a lip or tongue trill. The therapy duration consisted of 10 sessions (one session in a week) and the home training was given to all the participants. After completing 10 sessions, the subjects have undergone the same assessment protocol which was carried out in the baseline assessment. The results revealed that there was a significant difference seen in all the assessment measures after the therapy in the treatment group. After the intervention, vocal polyps were completely disappeared in two subjects and vocal adaptation was seen in one subject inspite of no regression in the size of the polyp. Among the five subjects, three subjects showed significantly improved voice quality after the exercise and no further laryngeal surgery was required. The improvement in the self-assessment of voice, size of the polyp, acoustic and perceptual parameters was attributed to the effect of lip trill and tongue trill exercise in the treatment of vocal polyp. Based on the results, the authors stated that lip trill or tongue trill can be used as an initial option for the treatment of vocal polyps regardless of the size and the type.

Guzman et al. (2018) investigated the impact of SOVTE with the dual-source of vibration in objective and subjective measures in dysphonic population. The study consisted of 84 dysphonic participants and their age ranged from 18 to 50 years. Patients with self-reported voice problems who had dysphonic voice on perceptual evaluation using the GRBAS scale were included in the study. The participants were assigned randomly to one of four SOVTE groups: (i) Water Resistant Therapy (ii) Tongue trills (iii) Lip trills (iv) Raspberry. Only 57 participants have completed the therapeutic procedure among the 84 participants. The treatment outcomes were assessed objectively through, EGG, acoustic measures and aerodynamic measures. The self-assessment rating was also done through Visual analog scale to assess the perception of muscle relaxation and resonant voice quality. The Spanish adaptation of the Vocal Tract Discomfort Scale (VTDS) was also administered to the participants. The aerodynamic parameters considered were phonation threshold pressure (cm H_2o); subglottal pressure (cm H_2o); glottal airflow (Lt/s) and glottal resistance (cm H_2O/Lt/S). The acoustic parameters considered were fundamental frequency (Hz) and sound pressure level (SPL). The EGG parameter considered was mean EGG contact quotient. Participants allotted to their respective groups were given their respective SOVTE for 30 minutes. The treatment procedure contained 3 sequential phonatory tasks (i) phonation of a vowel (ii) pitch gliding (iii) loudness variations. After the completion of 30 minutes session, the participants were asked to practice their respective SOVTE daily for a week. The assessment was done at three levels: (i) before the treatment (ii) immediately after the treatment (iii) after 1 week of therapy. The results showed that there is a significant difference between baseline and both post measures for the perception of muscle relaxation and resonant voice quality. There were no significant differences observed between Post 1 and Post 2 for any exercises. This finding indicated that all voice exercises have immediately improved the subjective self-perceived voice quality and it remained stable after 1 week of practice. Water Resistance therapy and raspberry has the maximum effect. The authors also stated that there was a significant decrease in VTDS values after a week of home training. Guzman et al concluded that SOVTEs with a secondary source of vibration might reduce vocal symptoms related to physical discomfort in subjects with voice complaints. The limitations in the present study were: (i) history of the dysphonia was not mentioned (ii) the given period of home training was not well documented (iii) between subject variability was not included though the exercises were completed by various set of participants.

Meerschman et al. (2019) examined the effect of three SOVT exercises on dysphonic population using multidimensional voice assessment. The SOVT exercises included in this study were (i) lip trill exercise; (ii) water resistance therapy (WRT) and (iii) straw phonation. This study consisted of 35 individuals (33 females and 2 males) with a mean age of 21 years. The subjects who were diagnosed with dysphonia were taken as participants in this study. These participants were randomly assigned to either of the four groups (i) lip trill group; (ii) water resistance therapy group; (iii) straw phonation group and (iv) control group. These participants received their respective SOVT therapy exercises twice a week for 3 months. The duration of each session was 30 minutes. There were totally 6 sessions and steps followed in each session are described in table 2.1.

Table 2.1

Procedure of the SOVTE Therapy by Meerschman et al (2019)

Sessions	Lip trill	WRT	Straw phonation
1	In step 1, participants were asked to sit/stand in their comfortable position and they were instructed to produce lip trills without voicing. In step 2, participants were instructed to produce lip trills with voicing.	Introduction of a tube with a length of 35 cm and a diameter of 10 mm in the water at 2 cm depth; blowing and phonating through the tube.	Introducing the straw of length 21 cm and 5 mm diameter; blowing and phonating through the straw.
2	In step 1, participants were	In step 1, participants were	In step 1, participants were

	asked to produce Lip trills without and with voicing. In step 2, participants were asked to produce lip trills in three different pitch variations; (i) gliding (ii) high and low pitch (iii) inflections. In step 3, participants were asked to produce lip trills by varying the loudness from (i) loud to soft (ii) soft to loud (iii) loud and soft.	asked to blow through the tube. In step 2, participants were asked to phonate using their habitual pitch through the tube immersed in water. In step 3, participants were asked to phonate through the tube in water using three different pitch variations; (i) gliding (ii) high and low pitch (iii) inflections. In step 3, participants were asked to phonate through the tube in water by varying the loudness from (i) loud to soft (ii) soft to loud (iii) loud and soft.	asked to blow through the straw. In step 2, participants were asked to phonate using their habitual pitch through the straw. In step 3, participants were asked to phonate through the straw using three different pitch variations; (i) gliding (ii) high and low pitch (iii) inflections. In step 3, participants were asked to phonate through the staw by varying the loudness from (i) loud to soft (ii) soft to loud (iii) loud and soft.
3	In step 1, participants were asked to produce lip trills by varying their pitch and loudness. In step 2, participants were asked to read the words and sentences using lip trills in a normal prosodic pattern. In step 3, participants were asked to read the words and sentences alternating between	In step 1, participants were asked to phonate through the tube in water by varying their pitch and loudness. In step 2, participants were asked to read the words and sentences through the tube in the water in a normal prosodic pattern. In step 3, participants were asked to read the	In step 1, participants were asked to phonate through the straw by varying their pitch and loudness. In step 2, participants were asked to read the words and sentences through the straw in a normal prosodic pattern. In step 3, participants were asked to read the words and sentences alternating between

	lip trill and normal open mouth reading.	words and sentences alternating between through the tube in water and normal open mouth reading.	through the straw and normal open mouth reading
4	In step 1, participants were asked to produce lip trills by varying their pitch and loudness. In step 2, participants were asked to read the words and sentences using lip trills in a normal prosodic pattern. In step 3, participants were asked to read the words and sentences alternating between lip trill and normal open mouth reading.	In step 1, participants were asked to phonate through the tube in water by varying their pitch and loudness. In step 2, participants were asked to read the words and sentences through the tube in the water in a normal prosodic pattern. In step 3, participants were asked to read the words and sentences alternating between through the tube in water and normal open mouth reading.	In step 1, participants were asked to phonate through the straw by varying their pitch and loudness. In step 2, participants were asked to read the words and sentences through the straw in a normal prosodic pattern. In step 3, participants were asked to read the words and sentences alternating between through the straw and normal open mouth reading
5	In step 1, participants were asked to read words and sentences using lip trills. In step 2, participants were asked to read the texts using lip trills. In step 3, participants were asked to read the texts alternating between lip trill and normal open mouth reading.	In step 1, participants were asked to read words and sentences through the tube in the water. In step 2, participants were asked to read the texts through the tube in the water. In step 3, participants were asked to read the texts alternating between through the tube in water and	In step 1, participants were asked to read words and sentences through the straw. In step 2, participants were asked to read the texts through the straw. In step 3, participants were asked to read the texts alternating between through the straw and normal open mouth reading

		normal open mouth reading.	
6	In step 1, participants were asked to read words, sentences and texts using lip trills. In step 2, participants were asked to speak spontaneously using lip trills. In step 3, participants were asked to speak spontaneously alternating between lip trill and an open mouth speaking.	In step 1, participants were asked to read words, sentences and texts through the tube in water. In step 2, participants were asked to speak spontaneously through the tube in water. In step 3, participants were asked to speak spontaneously alternating between through the tube in water and an open mouth speaking.	In step 1, participants were asked to read words, sentences and texts through the straw. In step 2, participants were asked to speak spontaneously through the straw. In step 3, participants were asked to speak spontaneously alternating between through the straw and an open mouth speaking.

The control group has received the placebo treatment for 1 hour a session. After the therapy sessions, the participants were encouraged to do home training of their respective SOVT exercise. A multidimensional voice measurement with both subjective and objective measures was done to investigate the participants' vocal quality, capacity, and psychosocial impact before and after 3 weeks of therapy. The objective measurements include Dysphonia Severity Index; Jitter and Acoustic Voice Quality Index. The subjective measures include the subject's self-report; Voice Handicap Index (VHI); Vocal tract discomfort scale (VTDS); questionnaire regarding the frequency of home practice and the subject's opinion regarding the therapy. Auditory perceptual evaluation using the GRBASI scale was also administered to the participants. There was a significant decrease in VHI in the lip trill and WRT group. There was a significant improvement seen in DSI in the lip trill and straw phonation group. There was also a significantly improved GRBASI score seen in the straw phonation group. There was a significant difference observed for the questionnaire based on the subject's opinion regarding the therapy across three groups. While comparing the three SOVTEs, straw phonation did not result in any improvement in self-report such as VHI. Whereas, Lip trill and WRT showed a significant improvement in VHI which indicated a better psychosocial impact, post-therapy. Also, among the three exercises, WRT was rated as the best by the participants and they reported improved voice quality after the sessions. This is the initial study that examined the effect of three different SOVTEs in dysphonic population using a multidimensional voice assessment. Also, this study supported that SOVTE had a positive impact on the outcomes of multidimensional voice assessment. The possible limitations of this study were (i) limited number of participants in each group (ii) laryngostroboscopic data were not included (iii) There were differences seen in the frequency of the treatment and home training between control and the SOVT groups.

Nam et al. (2019) investigated the effect of lip trills exercise in subjects with the glottal gap. There were 42 subjects enrolled in the study who were divided into three groups based on the glottal gap type: gap-only group (n=19), MTD group (n=13), and sulcus vocalis group (n=10). The age range of the participants was from 22 to 84 years. The patients were evaluated through subjective and objective methods prior to and after the therapy. The subjective evaluation included perceptual voice evaluation using the GRBAS scale and a subjective questionnaire such as voice handicap index (VHI-10), reflux symptom index, and vocal tract discomfort scale (VTDS). The objective evaluation included acoustic and aerodynamic analyses; and stroboscopic evaluation. The acoustic and EGG parameters considered were fundamental frequency, jitter, shimmer, noise-to harmonic ratio, speaking fundamental frequency, the closed quotient (CQ). The aerodynamic parameters considered were mean flow rate, subglottal pressure, and maximal phonation time (MPT). The presence and absence of glottal closure were examined by videolaryngostroboscopy. The patients were instructed to perform lip trills using their comfortable voice in four conditions: (i) pitch gliding; (ii) scaling; (iii) singing and (iv) reading. The voice therapy was carried out for 2 sessions a week across 2 weeks and home training was also given. The results of subjective and objective voice assessments were compared before and after lip trills in all subjects within and among the groups. The results showed significantly lower values in Grade (G), Roughness (R), Breathy (B) and S (strained) component in the GRBAS scale post therapy. It also revealed decreased jitter and shimmer values and increased CQ and MPT after the therapy. On subjective assessment, the mean scores in the VHI-10, VTDS and reflux symptom index questionnaires were significantly decreased. In stroboscopic evaluations post therapy, no glottal gap was seen in 16 subjects (38.1%), decreased in 21 subjects (50.0%), and present in 5 subjects (11.9%). Both objective and subjective parameters were improved significantly post therapy in the gap- only group. In the group with MTD, subjects showed significant improvement in both subjective and objective measures except MPT. Whereas, in the sulcus vocalis, significant improvement was seen in all the three subjective questionnaires and only in MPT in objective parameters. MPT was significantly improved in the sulcus vocalis group. The treatment effect has the highest effect in the gap-only group, lesser in the MTD group, and the least in the sulcus vocalis group. The authors attributed the improvement to the effect of lip trills that adjusted the subglottal pressure to prevent the hyper- or hypo adduction of the vocal cords. Authors concluded that lip trills can be used in combination with other voice therapy techniques for the effective treatment of various voice disorders. The limitations of this study were (i) therapy duration was not mentioned (ii) history of the voice problem was not reported (iii) wider age range of the participants and (iv) uneven distribution of participants in each group.

Vimal (2016) investigated the effect of the SOVTE- combined rigid and flexible straw phonation sequence on acoustic and electroglottographic parameters in vocally healthy individuals and hyper functional voice disorders. The study consisted of 40 participants with age ranges between 20-50 years divided into two groups. Group I consisted of 30 vocally healthy individuals with no voice complaints and group II consisted of 10 individuals with 6 hyper functional voice disorders with severity ranging from mild to moderate dysphonia. The study was carried out in three phases to evaluate the immediate and prolonged effect of SOVTE. Phase I was the baseline measurement where the participants were asked to phonate vowel /a/. In phase II, participants were asked to perform combined rigid and flexible straw phonation sequence. In flexible straw phonation exercise, participants were asked to phonate and hum "happy birthday" song through the flexible straw by keeping one end between the lips and the other end immersed in water. Next, the participants were asked to repeat the same procedure through the rigid straw placing one end in between the lips and the other end was free. The entire procedure was same for both the groups and duration of the exercise was 15 minutes. After the completion of exercise, post exercise measurement is done for group I and II. In phase III, 10 participants from group I and three participants from the group II were given home training where they were asked to practice both the exercises for duration of 15 minutes for 10 days. Then, the participants were evaluated using the same parameters which were used in phase I and II. The main outcome measures were acoustic parameters such as average fundamental frequency (mean F0); standard deviation of F0 (SDF0); F0- tremor frequency (Fftr); Amplitude tremor frequency (Fatr); Jitter percent; relative average perturbation (RAP); fundamental frequency variation (vF0); shimmer percent; amplitude perturbation quotient (APQ); noise to harmonic ratio (NHR); voice turbulence index (VTI); F0-tremor intensity index (Ftri); amplitude tremor intensity index (Atri); Fundamental frequency (F0); first formant frequency (F1); Second formant frequency (F2); frequency difference between F1 and F0; F0 tremor; Amplitude tremor (A- tremor); Signal to Noise ratio (SNR); Normalized Noise Energy (NNE); Harmonics to Noise Ratio (HNR) and EGG parameters such as Mean pitch, Contact Quotient (CQ), Open Quotient (OQ) and Speed Quotient (SQ). The author employed softwares such as Multidimensional Voice Profile; Dr Speech; Praat; Real time EGG in computerized speech lab 4500. The results of group I indicated that there is an increase in SQ and CQ in immediate posttest and an increase in CQ in prolonged post test. Group I also showed significant reduction in NNE, Fatr and OQ in immediate posttest and SQ and HNR in prolonged posttest. The results of group II showed a significant increase in SNR in immediate posttest and decrease in SQ, CQ, jitter and shimmer. Whereas, prolonged post test showed variability between the individuals in terms of both acoustic and EGG parameters. Out of the three subjects, two showed objective changes resulted in better voice quality. Comparison between groups I and II revealed a significant difference in SPI, SQ, NNE, HNR, SNR, F1-F0 in posttest condition. The author concluded that the findings of this study strengthened the hypothesis that SOVTE alters the supraglottal impedence thereby resulting in an efficient voice production with less effort. The limitations quoted in the study were (i) limited sample size (ii) only two laryngeal pathologies were considered (iii) perceptual evaluation was not included.

SOVTEs in professional voice users

Dargin and Searl (2015) investigated the effect of three SOVT exercise (lip trill, straw phonation and tongue trill) in singers using electroglottographic (EGG) and aerodynamic parameters. This study compared the EGG and aerodynamic measures before and immediately after the completion of SOVTs. The participants included in this study were four singers (3 males and 1 female) who were reported to be phononormals without any subjective voice complaints. The EGG and aerodynamic parameters considered were (i) closed quotient (%); (ii) mean expiratory airflow; (iii) oral air pressure; (iv) mean airflow during voicing; (v) laryngeal resistance and (vi) Sound pressure level (SPL). The baseline measurement was done to all the participants before the commencement of the exercise. The exercise phase consisted of four steps, initially the participants were randomly assigned to each of the three SOVTs and have completed the 2 minutes SOVT exercise which they have been assigned. Then, the post exercise measures were obtained. In the second step, the participants were randomly assigned to the next round of SOVT exercise and post measures were obtained. In the third step, again, the participants were randomly assigned to the final set of SOVT exercise and post measures were obtained.   In the final step, the aerodynamic and EGG measurements were done after 2 minutes rest period to assess the carry-over effect. The results showed that there was an increment seen in mean airflow, sound pressure level and EGG closed quotient immediately after the exercise. However, there significantly high variability was seen among the EGG and acoustic parameters between and within the subjects. Sound pressure level and airflow parameters were consistently increased for all the four singers after the exercise. However, variability was observed in the increment of % CQ between the subjects. In the carry over condition, %CQ was increased for three participants whereas sound pressure level was increased in only two of the participants. This was in contrast to the effect of individual SOVTEs. The authors stated that the increase in % CQ in carry over condition is due to the combined effect of three SOVTEs. The authors attributed the high variability between and within the subjects to the limited number of participants. The possible limitations in this study were (i) very small sample size; (ii) no break was given to participants before the commencement of next exercise and (iii) duration of the exercise was very brief (2 minutes).

Gaskill and Erickson (2008) examined the effect of lip trill exercise on glottal closed quotient between singers and non-singers. The study consisted of 25 male participants who had no subjective voice complaints or any other vocal fold pathologies. The participants were categorized into two groups. Group I consisted of 11 male singers with the age range of 24 to 64 years who are professionally trained with an experience of minimum 6 years. Group II consisted of 14 male non singers with age range of 18 to 46 years who were not professionally trained and had no singing experience. EGG closed quotient (CQ) was taken as an outcome measure. The data were obtained in two experimental setups: (i) experiment 1(group design) and (ii) experiment 2 (single subject design). The baseline procedure was similar to both experimental setups where the participants were asked to sustain a vowel /a/ at a predetermined loudness to obtain EGG

CQ. Experiment 1 consisted of 8 trained singers and 10 non singers and all of them were asked to perform the following tasks: (i) to sustain /a/ vowel (ii) to do continuous lip trill with voicing at their comfortable pitch and loudness for 1 minute (iii) to sustain /a/ vowel. In experiment 2, five singers and four non singers were participated. It was a single subject design (ABA design). All the participants were asked to perform the following three tasks: (i) sustain /a/ four times at their optimal pitch and loudness for 4 seconds each (ii) produce lip trills with voicing for 1 minute (iii) another four set of /a/ vowel at their optimal pitch and loudness for 4 seconds each. Four tokens of /a/ in the condition 1 was taken as a baseline (A) and it was compared with condition 2, during lip trill (B). EGG data was obtained from all the three conditions (pre lip trill, during lip trill and post lip trill) and CQ was analyzed. The results from the experiment I showed a decrease in CQ during the lip trill for both the groups, however non singers showed significant reduction in CQ during lip trill condition. Meanwhile, CQ of both the groups had returned to the pre trill value in post trill condition. The results from the experiment II revealed that all the four non singers showed decrement in CQ during lip trill when compared to pre trill condition. All the five singers showed significant decrease between pre trill and during lip trill condition. Also, three singers showed significant decrease between pre lip trill and post lip trill condition. The authors concluded that lip trill exercise changes the vocal behavior by promoting gentler adduction of the vocal folds and it can be used as a therapeutic exercise. The possible limitations in this study were (i) unequal age range distribution between the two groups and (ii) only males were included.

Chapter III

Method

Research Design

A mixed group design was used in the present study to compare the effect of lip trill exercise across three conditions (Baseline, Immediate and long term) and between the two groups (males and females).

Participants

The present study consisted of 40 phononormic individuals with the age range of 18-25 years who were residing in Mysuru, Karnataka, at the time of the study. The participants were categorized into two groups based on gender. Group I included 20 female participants with the mean age of 21.85 years, and group II included 20 male participants with the mean age of 22.1 years. Participants were selected based on the following inclusion and exclusion criteria.

Inclusion Criteria

- Participants with normal speech, language, hearing, and cognitive abilities were included.
- Participants who got a score of 0 in “G” of GRBAS scale (Auditory- perceptual evaluation of voice) and a score of less than 3 in self-reporting of voice problems using VHI-10 (Voice Handicap Index-10) were included.

Exclusion Criteria

Participants with the following history or issues were excluded from the study;

- Voice complaints or voice-related pathologies
- Any previous voice training/ professional voice users
- Upper respiratory tract infection/ respiratory disorders
- Hearing impairment
- Any prior history of head and neck surgery
- History of smoking and alcohol consumption
- History of neurological or psychological disorders.

Procedure

The objectives of the study were explained, and the written informed consent had been obtained from all the participants prior to the commencement of the study. All the procedures performed in the study were in accordance with the ethical standards of the institution. All the participants were perceptually evaluated by the researcher using the GRBAS scale (Hirano, 1981) through the phonation task, and the self-assessment tool, Voice Handicap Index-10 (Rosen et al., 2004) was administered before the commencement of the study. Only the participants who had scored ‘0’ in G of GRBAS scale and less than 3 in Voice Handicap Index-10 were included in this study.

The procedure involved acoustic and aerodynamic measurements of voice under three conditions: (i) Condition I (Baseline measurement); (ii) Condition II (Immediately after the lip trill exercise); and (iii) Condition III (after one week of home training). The acoustic and aerodynamic parameters considered were speaking fundamental frequency (sp F0), Voice Range Profile (VRP), Jitter (Jitt), Dysphonia Severity Index (DSI),and Maximum Phonation Time (MPT)

Speaking Fundamental Frequency

Speaking fundamental frequency (sp F0) is defined as an average of vocal fold vibrations during connected speech (Baken & Orlikoff, 2000). In the present study, counting task was used to assess the relaxed speaking voice.

Voice Range Profile

Voice range profile (VRP) is a display of vocal intensity versus frequency. It is an investigation procedure used to analyze the voice modalities, i.e., minimum and maximum loudness (Dynamic) and fundamental frequency (Pitch range) of an individual's voice. VRP parameters include: Minimum F0 (min F0); Maximum F0 (max F0); F0 range (F0r); Minimum I0 (min I0); Maximum I0 (max I0); and I0 range (I0r)

Jitter

Jitter is defined as a cycle to cycle variation of pitch/fundamental frequency. Jitter is a measurement of vocal stability.

Maximum Phonation Time (MPT)

MPT is an aerodynamic measure used to assess the glottis efficiency of a person. It is defined as the maximum time taken by the individual to sustain a vowel at their habitual pitch and loudness. It is usually measured in seconds.

Dysphonia Severity Index (DSI)

It is an objective measure to assess the overall voice quality of a person. DSI is derived based on the following parameters: Max F0 (in Hz), Min I0 (in dB), Jitter (%), and MPT (in seconds). If the score of DSI equals +5, it indicates perceptually normal voice, and -5 indicates severe dysphonia. The formula used to calculate DSI is; DSI=0.13 x MPT + 0.0053 x F_0-High – 0.26 x I-Low – 1.18 x Jitter (%) + 12.4 (Wuyts et al., 2000).

Instrumentation

Speaking fundamental frequency was measured from PRAAT software (*version* 6.1.14). Voice Range Profile (VRP) and Dysphonia Severity Index were calculated using the lingWAVES software, (voice clinic suite pro from Wevosys, Germany, 2018) and the corresponding SPL meter- microphone. Jitter and MPT were also obtained using the lingWAVES software while calculating the Dysphonia Severity Index.

The voice analysis was carried out in an acoustically treated room available in our institute, and the participants were asked to stand in front of the SPL meter-microphone and perform the tasks described below. The SPL meter- microphone was mounted using a tripod stand, and the microphone to mouth distance was kept at 10 cm.

Condition I (Baseline Measurement)

Initially, for the condition I (baseline measurement), speaking fundamental frequency during counting and VRP was obtained. For calculating speaking fundamental frequency, participants were given a counting task where they were instructed to recite the numbers from 21 to 25 at an average rate of speed and in their comfortable pitch and loudness.

Thereafter, for measuring the VRP, participants were asked to sustain a vowel /a/ in two conditions. At first, participants were encouraged to glide a vowel /a/ from their comfortable loudness to their loudest voice and from their comfortable loudness to their softest voice. Then, the participants were asked to prolong a vowel /a/ from their comfortable pitch to their possible highest pitch and from their comfortable pitch to their possible lowest pitch. This task was demonstrated to the participants by the examiner, and the feedback was given to the subjects when they produced glottal fry or their falsetto voice. During this task, the highest and the lowest pitch produced in their modal voice was only calculated. The glottal fry and falsetto voice produced by the participants were eliminated from the analysis by the examiner. Participants were asked to perform the task twice, and both the repetitions were recorded. Thus, the total frequency and the dynamic range of the participants' voices were obtained based on the above procedure.

For calculating the Jitter, participants were instructed to phonate a vowel /a/ for 4 seconds at their comfortable voice. For calculating Maximum phonation time (MPT), participants were asked to inhale deeply and sustain phonation of vowel /a/ as long as possible at their comfortable pitch and loudness. The longest phonation time out of three trials was chosen for MPT. Dysphonia severity index was also calculated using the inbuilt program in the software, which considered Maximum Fundamental frequency (Max F0), Minimum Intensity (Min I0), Jitter, and MPT for DSI calculation.

Condition II (Immediately after the lip trill exercise)

After the baseline measurement, participants were instructed to practice the SOVTE (lip trill exercise) for 3 minutes. This exercise consisted of 10 steps, and each lip trill steps had a specific time limit, and the total duration of the exercise was 3 minutes. Each Lip trill exercise step was explained and demonstrated by the examiner before the commencement of the exercise. Also, the participants were asked to watch the ten steps lip trill exercise video made by the researcher and then follow the exercise for 3 minutes.

The entire lip trill exercise steps/ procedure with the schedule is given in table 3.1. The stopwatch was used by the experimenter to monitor the time duration. After completing each exercise step, the next step was cued verbally by the researcher using the name of the next step (lip trill with phonation, without phonation, etc.). If any participants were unable to produce the lip trill, each step was modeled, and verbal prompts were given by the researcher, such as asking the subject to protrude the lips by placing the hand on their cheeks.

Table 3.1

Lip trill exercise steps with the time duration

Steps	**Exercise**	**Time Duration**
Step 1	Lip trills without phonation	15 seconds
Step 2	Lip trill with phonation	15 seconds
Step 3	Lip trills with pitch gliding (ascending)	15 seconds
Step 4	Lip trills with pitch gliding (descending)	15 seconds
Step 5	Lip trills with phonation (soft voice)	15 seconds
Step 6	Lip trills with phonation (loud voice)	15 seconds
Step 7	Lip trills when reading words	15 seconds
Step 8	Lip trills when reading sentences	15 seconds
Step 9	Alternating between lip trill reading and normal oral (open mouth) reading in sentences	30 seconds
Step 10	Alternating between counting using lip trill and normal open mouth counting	30 seconds

Description of the Lip Trill Exercise

Step 1 (Lip trills without phonation). Participants were asked to take a deep breath and to produce lip trills without phonation or voicing at the laryngeal level for 15 seconds.

Step 2 (Lip trill with phonation). Participants were asked to take a deep breath and to produce lip trills with phonation or voicing for 15 seconds.

Step 3 (Lip trills with ascending pitch gliding).For this step, the participants were asked to produce lip trills from their comfortable pitch level to highest possible pitch in a glide manner/pattern for 15 seconds

Step 4 (Lip trills with descending pitch gliding).In this step, the participants were asked to produce lip trills with pitch gliding in a (descending) manner. That is, the participants were asked to produce lip trills from their comfortable pitch level to lowest possible pitch in a glide manner/pattern for 15 seconds

Step 5 (Lip trills with soft phonation). In this step, the participants were asked to produce lip trills with phonation in their soft voice for 15 seconds.

Step 6 (Lip trills with soft phonation). In this step, the participants were asked to produce lip trills with phonation in their loud voice for 15 seconds.

Step 7 (Lip trills when reading words). In this step, the participants were asked to read a list of words taken from the standardized articulation test, The Edinburgh Articulation Test (Bogle et al., 1971) using lip trills for 15 seconds.

Step 8 (Lip trills when reading sentences). In this step, the participants were asked to read the standard “The Rainbow passage” using lip trills for 15 seconds.

Step 9 (Alternating between lip trill and oral reading in sentences). In this step, the participants were asked to read the same standard passage alternatively using lip trills and normal oral (open mouth) reading for 30 seconds.

Step 10 (Alternating between lip trill and oral counting). In this step, the participants were asked to count numbers from 1 to 30 alternatively using lip trills and normal open mouth speaking for 30 seconds.

These exercise steps 1 to 10 were performed only once for a 3-minute duration continuously without any breaks offered in between the steps. After completion of 3 minutes of lip trill exercise (ten steps), post acoustic and aerodynamic measures was done immediately to calculate the immediate effect of lip trill exercise.

Condition III (After One Week of Home Training)

After the immediate post-exercise measurement, the participants were given home training and asked to follow the exercise one time in a day for a week. To monitor the compliance of the participants, a Whatsapp message was sent daily to each participant. Participants were asked to send the video recording of their lip trill training daily for the entire week, and also log sheet was given to note down their home training details and was asked to submit their log sheet at the end of the home training. After one week, participants were called for post-one-week acoustic and aerodynamic voice recordings to investigate the benefits of long term lip trill exercise (condition III).

The measured outcome parameters were

- Speaking F0 (sp F0) (Hz)
- Voice Range Profile (MinF0 (Hz); MaxF0 (Hz); F0r (Hz); Min I0 (dB A); Max I0 (dB A); and I0r (dB A))
- Maximum Phonation Time (MPT) (seconds)
- Jitter (Jitt) (%)
- Dysphonia Severity Index (DSI).

Analysis

The measured raw data of the acoustic and aerodynamic parameters were tabled and compared between the two groups (Males vs Females) and across three conditions, i.e.

- Condition I: Before the commencement of the exercise (baseline)
- Condition II: Immediately after the exercise (immediate)
- Condition III: After a week of home training (long term)

Statistical Analysis

The collected data were subjected to statistical analysis using SPSS software, and the appropriate statistical tests were carried out based on the Shapiro Wilk's test of Normality. The results showed that most of the parameters in the data were normally distributed (p-value > 0.05) except for a few parameters. Jitter in baseline phase; Max I0 and Jitter in immediate phase; Sp F0 and min I0 in long terms in males and Jitter in the baseline, immediate and long term phase, and Max F0 in immediate phase in females are the parameters which were not normally distributed. For the parameters which followed a normal distribution, parametric test such as one way repeated measures ANOVA and Bonferroni pairwise comparison was used to compare the effect of lip trill exercise among three conditions. For the parameters which were not normally distributed, nonparametric test such as the Friedman test and Wilcoxon signed-rank test was used. One-way MANOVA and the Mann-Whitney test was used to investigate the gender effect.

Chapter IV

Results

The primary objectives of this study were to compare the immediate and long term effect of lip trill exercise from the baseline measurement and to explore the gender effect in three conditions (i) Baseline (BL), (ii) Immediate(IMM) and (iii) long term (LT) between males and females. The primary outcome measures were: (i) Speaking F0 (sp F0), (ii) Minimum F0 (min F0), (iii) Maximum F0 (max F0), (iv) F0 range (F0r), (v) Minimum I0 (min I0), (vi) Maximum I0 (max I0), (vii) I0 range (I0r), (viii) Maximum Phonation Duration (MPD), (ix) Jitter (Jitt) and (x) Dysphonia Severity Index.

Statistical tests were carried out for the parameters mentioned above using the "Statistical Package for Social Sciences software (SPSS, version.20.0)".

The statistical tests used in the present study were:

1. Shapiro Wilk's test of Normality
2. Descriptive Statistics
3. One way MANOVA
4. Mann-Whitney test
5. Friedman test
6. Wilcoxon signed-rank test
7. One way repeated measures ANOVA
8. Bonferroni pairwise comparison

The results are summarized under the following subheadings

4.1 Normality test results

4.2 Results of the descriptive analysis

4.3 Effect of lip trill exercise: comparison among the three conditions on voice parameters

4.4 Effects of gender

4.1 Normality Test Results

Shapiro Wilk's test was carried out to explore the normality distribution among the data. The results showed that most of the parameters in the data were normally distributed (p-value > 0.05) except for a few parameters. Hence, the parametric test such as one way repeated measures ANOVA was done to compare the effect of lip trill exercise among three conditions for the parameters which are normally distributed. If any significance was seen among the parameters in three phases, Bonferroni pairwise comparison was done to investigate the significance between any of the two conditions (BL vs IMM; IMM vs LT; BL vs LT). For the parameters which were not normally distributed non-parametric test such as the Friedman test was used to compare the effect among the three conditions and Wilcoxon signed-rank test was done for pairwise comparison. To investigate the gender effect, one-way MANOVA was used for normally distributed parameters, and the Mann-Whitney test was used for the parameters which were not normally distributed.

4.2 Results of the Descriptive Analysis

The mean, median, and standard deviation (SD) scores of the outcome parameters for females are given in table 4.1.

Table 4.1

Mean, Median, and SD scores of the Outcome measures Parameters for Female Group

Parameter	Baseline			Immediate			Long term		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Sp F0 (Hz)	234.15	15.80	236.50	245.60	15.31	248.50	240.30	14.03	242.50
Min F0(Hz)	161.70	18.01	159.00	150.0	28.02	150.00	127.55	24.36	125.00
Max F0(Hz)	440.25	66.04	450.00	463.50	67.80	454.50	558.95	110.65	538.50
F0r	278.70	65.62	285.00	315.10	57.21	314.00	435.05	116.51	414.50
MinI0(dBA)	57.40	7.37	59.00	52.15	5.76	52.00	49.60	4.51	50.50
MaxI0(dBA)	106.40	7.10	103.50	106.65	6.94	106.00	110.30	6.95	109.50
I0r	49.25	8.94	48.5	54.50	7.68	55.00	60.70	7.71	60.00
MPT (s)	13.00	2.77	13.00	15.15	3.51	15.00	15.05	4.01	15.00
Jitt (%)	0 . 20	0.16	0.15	0.21	0.19	0.16	0.25	0.15	0.22
DSI	1.35	2.02	1.05	3.05	1.25	3.30	4.10	1.49	3.80

Table 4.1 revealed an increase in spF0 immediately after the exercise and a decrement was seen after a week of home training. Max F0, F0r, and I0r showed a consistent increment throughout the three conditions. Min F0 and Min I0 were decreased in the immediate and long term phase when compared to the baseline phase. Other parameters didn't show any trend throughout the three conditions. The mean, median, and

SD scores of the measured parameters are tabulated in the following table 4.2 for the male group.

Table 4.2

Mean, Median, and SD Scores of the Outcome Measures for Male group

Parameter	Baseline			Immediate			Long term		
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median
Sp F0 (Hz)	136.75	19.17	135.50	150.05	21.78	147.00	137.45	19.70	130.50
Min F0 (Hz)	104.50	16.33	98.00	95.00	18.04	95.00	94.10	16.67	96.00
Max F0 (Hz)	303.95	44.18	299.00	325.90	44.69	322.00	388.85	69.46	373.50
F0r	199.45	50.04	192.00	240.35	66.05	222.50	294.75	64.74	276.00
MinI0(dBA)	51.00	7.29	51.50	52.85	4.51	53.50	51.05	4.39	52.00
MaxI0(dBA)	112.10	6.23	110.00	111.35	7.68	112.00	114.15	6.01	114.00
I0r	61.10	10.38	59.50	58.50	8.98	61.50	63.45	6.26	61.00
MPT (s)	16.80	4.95	16.50	17.45	5.90	17.50	18.30	5.15	19.00
Jitt (%)	0.26	0.23	0.16	0.18	0.09	0.14	0.17	0.09	0.16
DSI	2.77	2.47	2.35	2.51	1.88	2.65	3.40	1.27	3.15

The results from table 4.2 revealed that an increase in sp F0 was seen in the immediate condition followed by spF0 returning to its baseline in the long term condition. The parameters such as F0r and MPT showed a consistent increment throughout the three phases. The other parameters such as min F0 and min I0 were decreased in immediate and long term conditions when compared to the baseline.

4.3 Effect of Lip Trill Exercise: Comparison among the Three Conditions on Voice Parameters

Comparison of Speaking F0 across Three Conditions

The mean and median scores of spF0 across the three conditions for the two groups (group I and II) are depicted in figure 4.1.a and 4.1.b, respectively.

Figure 4.1.a

Comparison of Sp F0 across Three Conditions in Female Group

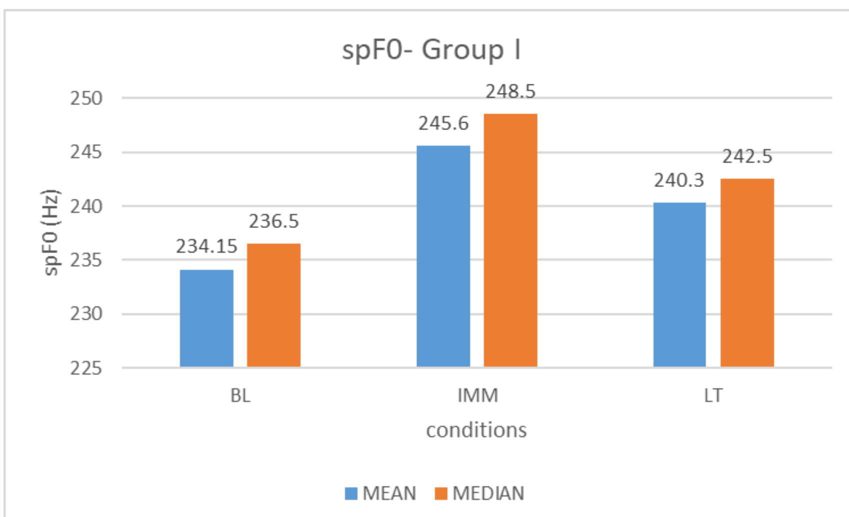

Figure 4.1.b

Comparison of SpF0 across three conditions in male group

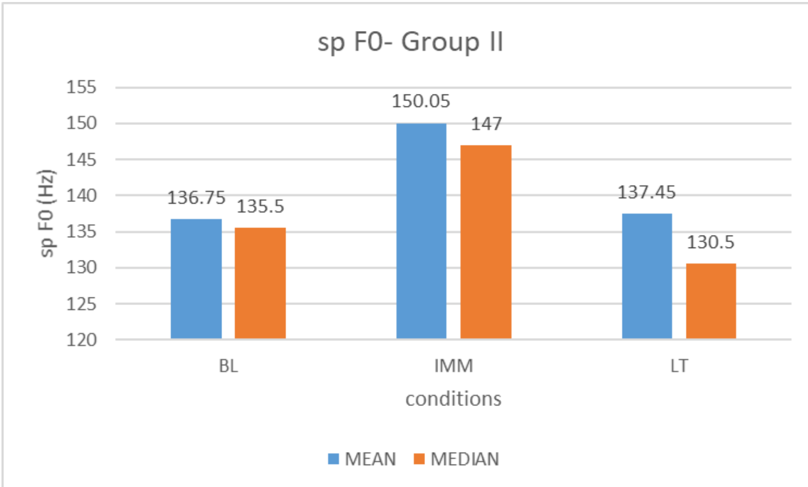

Figure 4.1.a revealed that sp F0 is increased (mean: 245.60 Hz; median: 248.50 Hz) immediately after the three minute of lip trill exercise when compared to the baseline (mean: 234.15 Hz; median: 236.50 Hz) and it has decreased after one week of home training (mean: 240.30 Hz; median: 242.50 Hz) in the female group. Figure 4.1.b revealed that sp F0 was also increased in male group immediately after the exercise (mean: 150.05 Hz; median: 147 Hz) when compared to the baseline (mean: 136.75 Hz; median: 135.50 Hz) and it has returned to the baseline value after one week of home training (mean: 137.45 Hz; median: 130.50 Hz). Friedman's test was used to calculate the test significance for sp F0 as it was not normally distributed. Results from the Friedman's test revealed that sp F0 was statistically significant across the three conditions for both the groups ($p<0.05$). Hence, the Wilcoxon signed-rank test was used to evaluate the significance between any of the two conditions (BL vs IMM; IMM vs LT; BL vs LT) for

both the groups. The Wilcoxon signed-rank test for the group I (female participants) revealed a statistically significant difference between baseline and immediate ($p<0.05$); between immediate and long term ($p<0.05$); and also between baseline and long term ($p<0.05$) conditions. Sp F0 is significantly increased in the immediate and long term conditions when compared to the baseline condition. The Wilcoxon signed-rank test for group II (male participants) revealed that there is a statistically significant difference seen between baseline and immediate ($p<0.05$) and between immediate and long term ($p<0.05$) conditions. There was no statistically significant difference observed between baseline and long term ($p>0.05$) conditions. Sp F0 is significantly increased in the immediate condition when compared to the baseline and long term conditions in the male group. Results from the Wilcoxon signed-rank test is presented in table 4.3.

Table 4.3

Results of the Wilcoxon Signed-Rank Test for Speaking F0 in Group I and II

Parameter	**Conditions**	**Group I**		**Group II**	
		/Z/	p	/Z/	p
Speaking F0	BL vs IMM	3.886	0.00*	3.922	0.00*
	BL vs LT	2.316	0.02*	0.464	0.64
	IMM vs LT	2.186	0.03*	3.624	0.00*

(* indicates significance at 0.05 level)

Comparison of Min F0 across Three Conditions

The mean and median scores of Min F0 across the three conditions for group I and group II are shown in figure 4.2.a and 4.2.b, respectively.

Figure 4.2.a

Comparison of Min F0 across Three Conditions in the Female Group

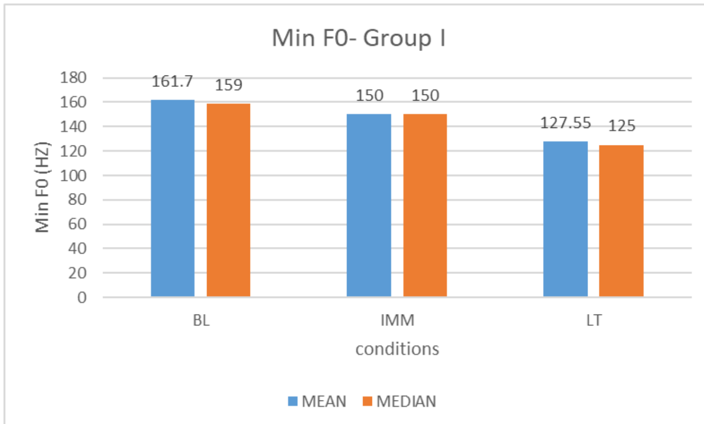

Figure 4.2.b

Comparison of Min F0 across Three Conditions in the Male Group

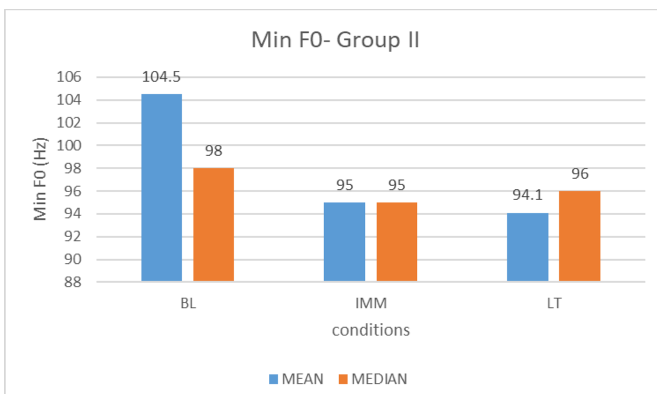

Figure 4.2.a and 4.2.b showed that Min F0 is consistently decreased for both the groups in the immediate (mean: 159 Hz; median: 150 Hz; for the group I; mean: 98 Hz, median: 95 Hz; for group II) and long term conditions (mean: 127.55 Hz; median: 125 Hz for the group I; mean: 94.1 Hz, median: 96 Hz for group II) when compared to the baseline condition (mean: 161.70 Hz; median: 159 Hz for the group I; mean: 104.5 Hz, median: 98

Hz for group II). One way repeated measures ANOVA was used to test the significance for min F0 as it followed the normal distribution. Results from the One way repeated measures ANOVA revealed that there was a statistically significant difference observed across the three conditions for group I ($p<0.05$), and no statistical significance was seen for group II ($p=0.05$). Hence, the Bonferroni pairwise comparison was done to evaluate the significance between any of the two conditions for the group I and the results showed that there is a statistically significant difference present between immediate and long term ($p<0.05$); and between baseline and long term ($p<0.05$) conditions. Min F0 is significantly decreased in the long term conditions when compared to the baseline condition. Results from the Bonferroni pairwise comparison is presented in table 4.4.

Table 4.4

Results of Bonferroni pairwise comparison for Min F0 in Group I (Females)

Parameter	Conditions		Group I	
			Mean difference	p value
Min F0	BL	IMM	11.70	0.19
		LT	34.15	0.00*
	IMM	BL	11.70	0.19
		LT	22.45	0.01*
	LT	BL	34.15	0.00*
		IMM	22.45	0.01*

(* indicates significance at 0.05 level)

Comparison of Max F0 across Three Conditions

The mean and median scores of Max F0 across the three conditions for the two groups (group I and II) are illustrated in figure 4.3.a and 4.3.b, respectively.

Figure 4.3.a

Comparison of Max F0 across Three Conditions in the Female Group

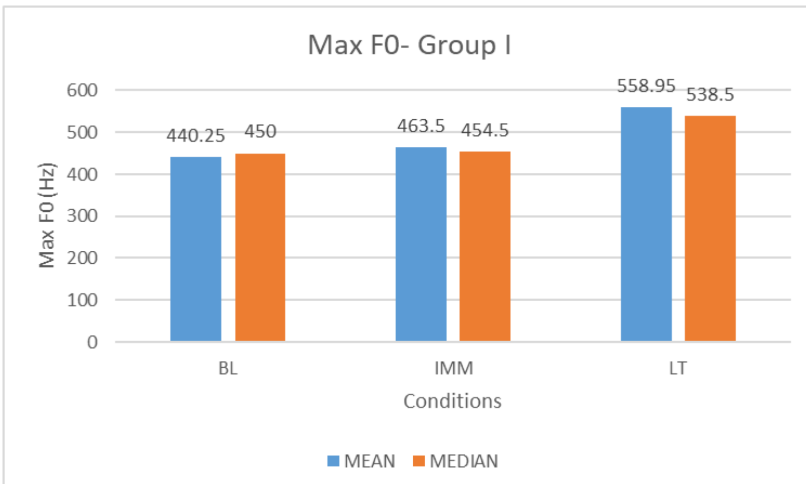

Figure 4.3.b

Comparison of Max F0 across Three Conditions in the Male Group.

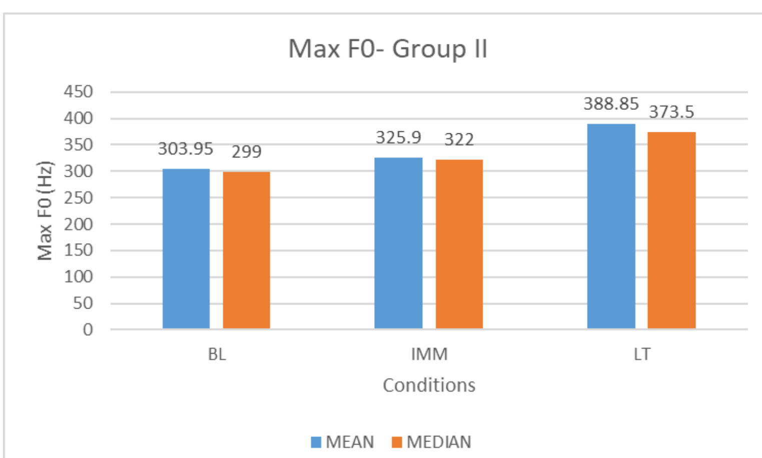

Figure 4.3.a and 4.3.b depicted that Max F0 has increased consistently for both the groups in the immediate (mean: 463.50 Hz; median: 454.50 Hz for the group I; mean: 325.90 Hz, median: 322 Hz for group II) and long term conditions (mean: 558.95 Hz; median: 538.50 Hz; SD: 110.65 for the group I; mean: 388.85 Hz, median: 372.50 Hz for group II) when compared to the baseline condition (mean: 440.25 Hz; median: 450.00 Hz for the group I; mean: 303.95 Hz, median: 299 Hz for group II). Friedman's test was used to calculate the test of significance for max F0,and the results revealed that there was a statistically significant difference seen in max F0 across the three conditions for both the groups ($p<0.05$). Hence, the Wilcoxon signed-rank test was used to evaluate the pair-wise comparison for both the groups and the results showed that there is a statistically significant difference seen between baseline and immediate ($p<0.05$); between immediate and long term ($p<0.05$); and also between baseline and long term ($p<0.05$) conditions for both the groups. Max F0 is significantly increased in the immediate and long term conditions when compared to the baseline condition for both the groups. Results from the Wilcoxon signed-rank test is given in table 4.5.

Table 4.5

Results of the Wilcoxon Signed-Rank Test for Max F0 for Group I and II

Parameter	Conditions	Group I		Group II	
		/Z/	p	/Z/	p
Max F0	BL vs IMM	2.15	0.03*	3.46	0.00*
	BL vs LT	3.82	0.00*	3.92	0.00*
	IMM vs LT	3.92	0.00*	3.82	0.00*

(* indicates significant at 0.05 level)

Comparison of F0r across Three Conditions

The mean and median scores of F0r across the three conditions for group I and group II are shown in figure 4.4.a and 4.4.b, respectively.

Figure 4.4.a

Comparison of F0r across Three Conditions in the Female Group

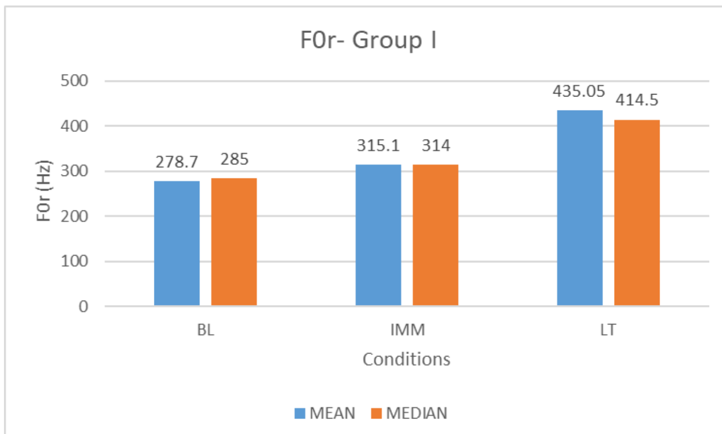

Figure 4.4.b

Comparison of F0r across Three Conditions in the Male Group.

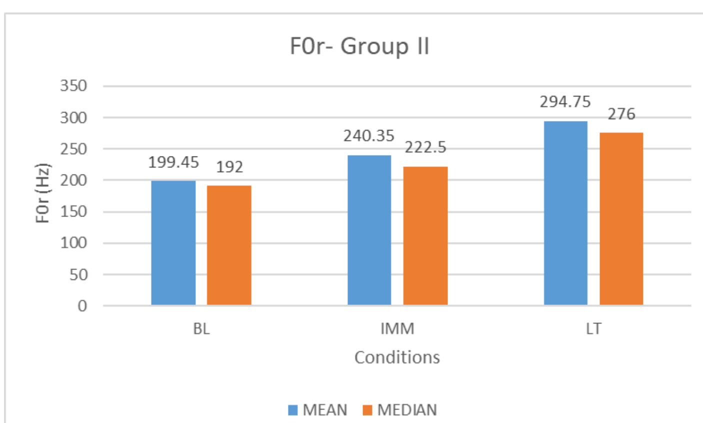

Figure 4.4.a and 4.4.b revealed that F0 range was consistently increased for both the groups in the immediate (mean: 315.10 Hz; median:314 Hz for the group I; mean: 240.35 Hz, median: 222.50 Hz for group II) and long term conditions (mean: 435.05 Hz; median: 414.50 Hz for the group I; mean: 294.75 Hz; median: 276 Hz; for group II) when compared to the baseline condition (mean: 278.70 Hz; median: 285 Hz for the group I; mean: 199.45 Hz, median: 192 Hz for group II). One way repeated measures ANOVA was used to test the significance and the results showed that there was a statistically significant difference observed across the three conditions for both the groups ($p<0.05$). Hence, the Bonferroni pair-wise comparison was done to evaluate the significance between any of the two conditions for the two groups and the results showed that there is a statistically significant difference present between baseline and immediate ($p<0.05$); between immediate and long term ($p<0.05$); and also between baseline and long term ($p<0.05$) conditions. F0 range has significantly increased in the immediate and long term conditions when compared to the baseline condition. Results from the Bonferroni pair-wise comparison is presented in table 4.6.

Table 4.6

Results of Bonferroni Pairwise Comparison for F0Range in Group I and II

Parameter	**Conditions**		**Group I**		**Group II**	
			Mean difference	p value	Mean difference	p value
F0 range	BL	IMM	36.40	0.01*	40.90	0.00*
		LT	156.35	0.00*	95.30	0.00*
	IMM	BL	36.40	0.01*	40.90	0.00*
		LT	119.95	0.00*	54.40	0.00*
	LT	BL	156.35	0.00*	95.30	0.00*
		IMM	119.95	0.00*	54.40	0.00*

(* indicates significance at 0.05 level)

Comparison of Min I0 across Three Conditions

The mean and median scores of Min I0 across the three conditions for the two groups (group I and II) are illustrated in figure 4.5 a and 4.5 b, respectively.

Figure 4.5.a

Comparison of Min I0 across Three Conditions in the Female group

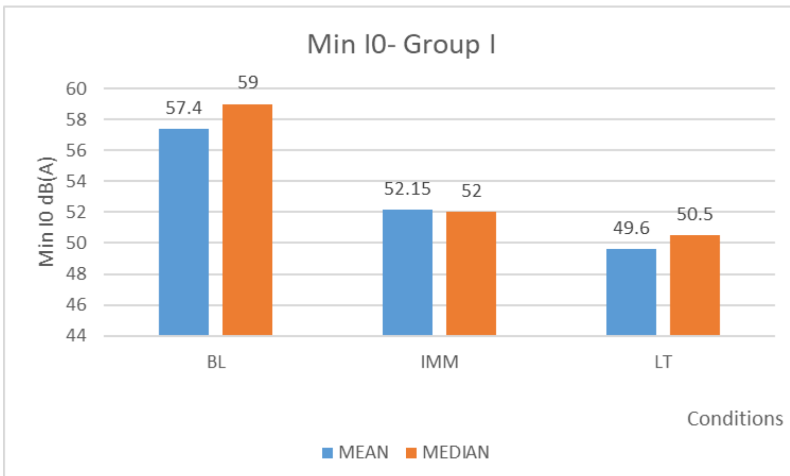

Figure 4.5.b

Comparison of Min I0 across Three Conditions in the Male Group

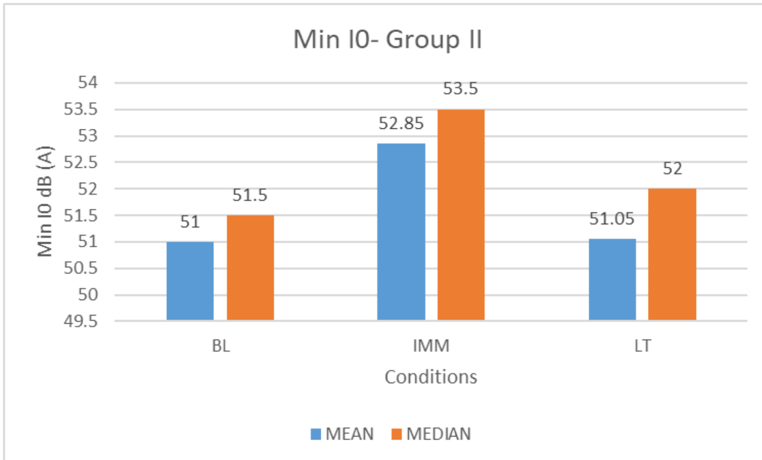

Figure 4.5.a revealed that min I0 was decreased in the immediate (mean: 52.15 dB (A); median: 52 dB (A); SD: 5.76) and the long term condition (mean: 49.60 dB (A); median: 50.50 dB (A); SD: 4.51) compared to the baseline condition (mean: 57.40 dB (A); median: 59 dB (A); SD: 7.379) in the female group. Figure4.5.b showed that there was no change observed in min I0 across the three conditions in the male group. Friedman's test was used, and the results revealed that there was a statistically significant difference seen in min I0 across the three conditions for group I ($p<0.05$). No statistical significance was observed across the three conditions for group II ($p>0.05$). Hence, the Wilcoxon signed-rank test was used to evaluate the pair-wise significance between any of the two conditions for group I and the results showed that there is a statistically significant difference seen between baseline and immediate ($p<0.05$), and also between baseline and long term ($p<0.05$) conditions. No statistical significance was observed between immediate and long term conditions ($p>0.05$). Results from the Wilcoxon

signed-rank test is presented in table 4.7. Min I0 is statistically decreased in the immediate and long term condition when compared to the baseline for the female group. Min I0 is relatively constant across the three conditions for the male group.

Table 4.7

Results of the Wilcoxon Signed-Rank Test for Min I0 in Group I(females)

Parameter	**Conditions**	**Group I**	
		/Z/	p
Min I0	BL vs IMM	2.39	0.01*
	BL vs LT	3.30	0.00*
	IMM vs LT	1.39	0.16

(* indicates significance at 0.05 level)

Comparison of Max I0 across Three Conditions

The mean and median scores of Max I0 across the three conditions for the two groups (group I and II) are illustrated in figure 4.6.a and 4.6.b, respectively.

Figure 4.6.a

Comparison of Max I0 across Three Conditions in the Female Group

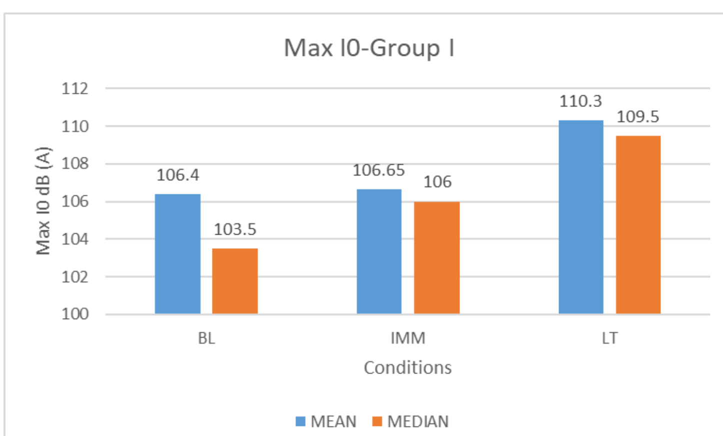

Figure 4.6.b

Comparison of Max I0 across Three Conditions in the Male Group

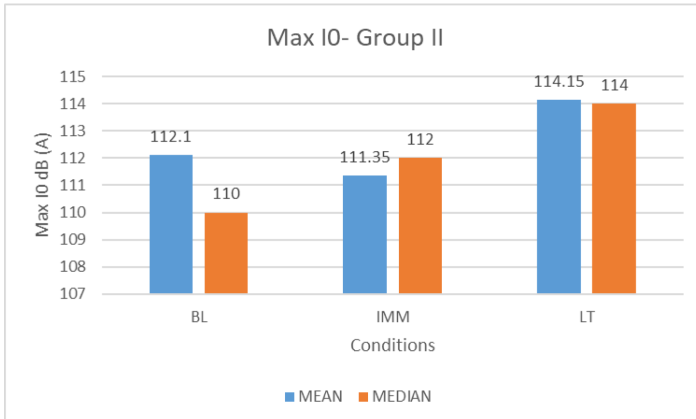

Figure 6.a revealed that Max I0 showed an increment in the long term condition (mean: 110.30 dB (A); median: 109.50 dB (A)) when compared to the immediate (mean: 106.65 dB (A); median: 106 dB (A)) and the baseline conditions (mean: 106.40 dB (A); median: 103.50 dB (A)) in the female group. Figure 4.6.b showed that there was no such increment observed in max I0 across the three conditions in the male group. Max I0 was relatively consistent across the three conditions in the male group. Friedman's test was used, and the results revealed that there was a statistically significant difference seen in max I0 across the three conditions for group I ($p<0.05$), and no statistical significance was seen across the three conditions for group II ($p>0.05$). Pairwise comparison was done using the Wilcoxon signed-rank test for the female group, and the results showed that there is a statistically significant difference seen between the immediate and long term($p<0.05$)and also between baseline and long term ($p<0.05$) conditions. No statistical significance was observed between baseline and immediate conditions ($p>0.05$). Max I0

showed a statistically significant increment in the long term condition when compared to the immediate and the baseline conditions in the female group. Results from the Wilcoxon signed-rank test is presented in table 4.8.

Table 4.8

Results of the Wilcoxon Signed-rank Test for Max I0 for Group I (females)

Parameter	Conditions	Group I	
		/Z/	P
Max I0	BL vs IMM	0.13	0.89
	BL vs LT	2.22	0.02*
	IMM vs LT	2.38	0.01*

(* indicates significance at 0.05 level)

Comparison of I0r across Three Conditions

The mean and median scores of I0 range across the three conditions for the two groups (group I and II) are illustrated in figure 4.7.a and 4.7.b, respectively.

Figure 4.7.a

Comparison of I0r across three conditions in the female group

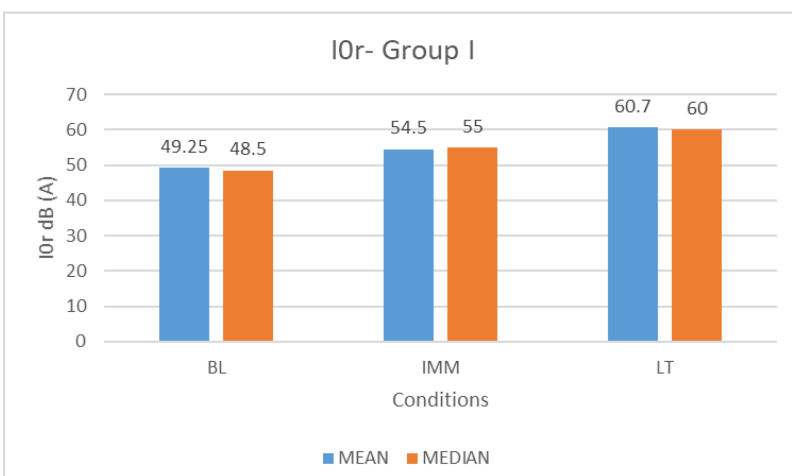

Figure 4.7.b

Comparison of I0r across three conditions in the male group

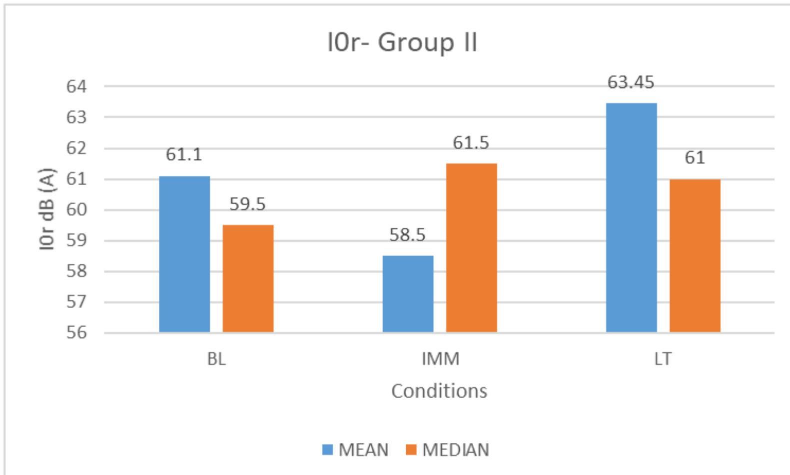

Figure 4.7.a and 4.7.b revealed that I0 range was increased for both the groups in the immediate (mean: 54.50 dB (A); median:55 dB (A) for the group I; mean: 58.50 dB (A), median: 61.50 dB (A) for group II) and long term conditions (mean: 60 dB (A); median: 60 dB (A) for the group I; mean: 63.45 dB (A), median: 61 dB (A) for group II) when compared to the baseline condition (mean: 49.25 dB (A); median: 48.5 dB (A) for the group I; mean: 61.10 dB (A), median: 59.50 dB (A)for group II). One way repeated measures ANOVA was used to test the significance, and the results revealed that there was a statistically significant difference seen in I0 range across the three conditions for group I ($p<0.05$), and statistical significance was not observed for group II ($p>0.05$). Hence, Bonferroni pair-wise comparison testwas used to evaluate the significance between any of the two conditions for the female group and the results showed that there is a statistically significant difference present between baseline and immediate ($p<0.05$); between immediate and long term ($p<0.05$); and also between baseline and long term

(p<0.05) conditions. I0 range is significantly larger in the immediate and long term conditions when compared to the baseline condition for the female group. Results from Bonferroni pair-wise comparison are presented in table 4.9.

Table 4.9

Results of Bonferroni Pairwise Comparison for I0 Range in Group I (Females)

Parameter	**Conditions**		**Group I**	
			Mean difference	p value
I0 range	BL	IMM	5.25	0.03*
		LT	11.45	0.00*
	IMM	BL	5.20	0.03*
		LT	6.20	0.01*
	LT	BL	11.45	0.00*
		IMM	6.20	0.01*

(* indicates significance at 0.05 level)

Comparison of MPT across Three Conditions

The mean and median scores of MPT across the three conditions for group I and group II are shown in figure 4.8.a and 4.8.b, respectively.

Figure 4.8.a

Comparison of MPT across Three Conditions in the Female Group

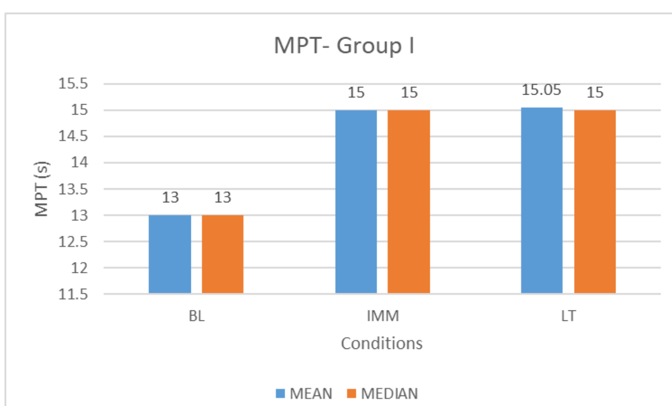

Figure 4.8.b

Comparison of MPT across Three Conditions in the Male Group

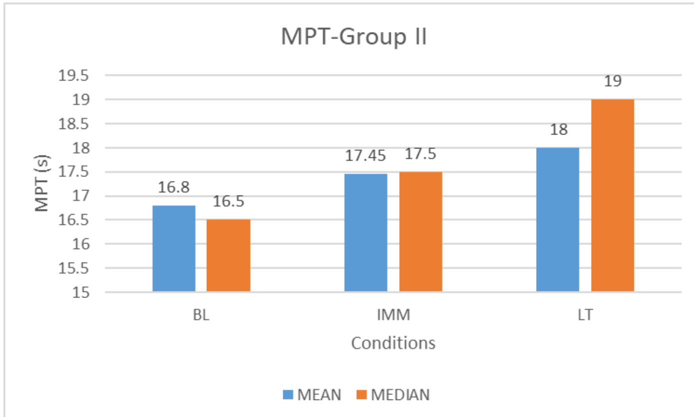

Fig 4.8.a and 4.8.b revealed that MPT was increased for both the groups in the immediate (mean: 15.15 s; median:15 s for the group I; mean: 17.45 s, median: 17.50 s for group II) and long term conditions (mean: 15.05 s; median: 15 s; for the group I; mean: 18.30 s; median: 19 s for group II) when compared to the baseline condition (mean: 13 s; median: 13 s for the group I; mean: 16.80 s, median: 16.5 s for group II). One way repeated measures ANOVA was used to test the significance and the results showed that there was a statistically significant difference observed across the three conditions for both the groups ($p<0.05$). Hence, the Bonferroni pair-wise comparison was done to evaluate the significance between any of the two conditions for the two groups. The results showed that there is a statistically significant difference present between baseline and immediate ($p<0.05$), and between baseline and long term ($p<0.05$) conditions for group I and not between immediate and long-term conditions. MPT has significantly increased in group I from baseline condition to immediate and long term conditions. For group II, the Bonferroni pair-wise comparison results revealed that there

is a statistically significant difference present between baseline and long term($p<0.05$) condition.MPT has significantly increased in the long term condition when compared to the baseline and the immediate conditions for the male group. Results from the Bonferroni pair-wise comparison is presented in table 4.10

Table 4.10

Results of Bonferroni Pair-wise Comparison for MPT in Group I and II

Parameter	Conditions		Group I		Group II	
			Mean difference	p value	Mean difference	p value
MPT	BL	IMM	2.15	0.00*	0.65	0.65
		LT	2.05	0.02*	1.50	0.03*
	IMM	BL	2.15	0.00*	0.65	0.65
		LT	0.10	1.00	0.85	0.32
	LT	BL	2.05	0.02*	1.50	0.03*
		IMM	0.10	1.00	0.85	0.32

(* indicates significance at 0.05 level)

Comparison of Jitter across Three Conditions

The mean and median scores of jitter across the three conditions for the two groups(group I and II) are depicted in figure 4.9.a and 4.9.b, respectively.

Figure 4.9.a

Comparison of Jitter across Three Conditions in the Female Group

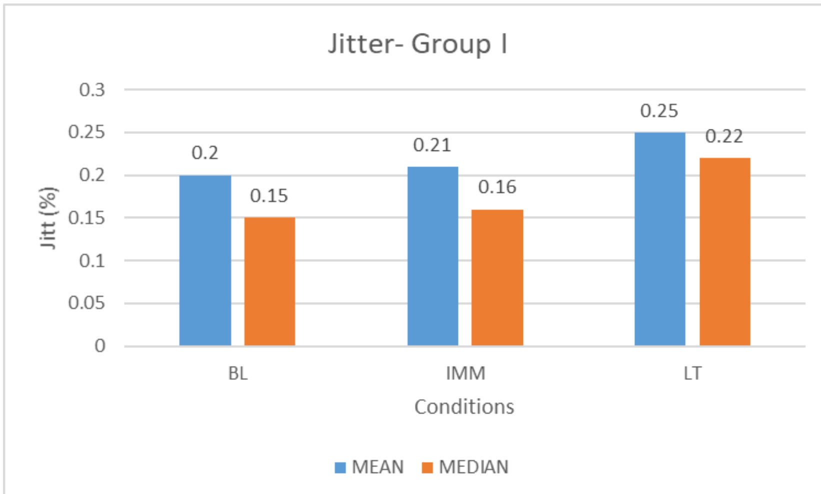

Figure 4.9.b

Comparison of Jitter across Three Conditions in the Male Group

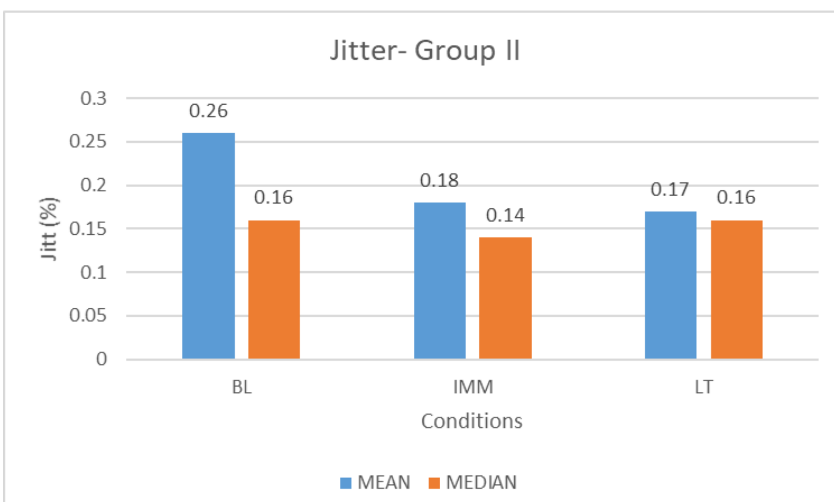

Figure 4.9.a and 4.9.b revealed that jitter did not change across the three conditions for both the group. Friedman's test was used to calculate the test significance for jitter as it was not normally distributed. Results from the Friedman's test revealed that there was no statistically significant difference seen in jitter across the three conditions for both the groups ($p>0.05$).

Comparison of DSI across three conditions

The mean and median scores of DSI across the three conditions for the two groups (group I and II) are illustrated in figure 4.10.a and 4.10.b, respectively.

Figure 4.10.a

Comparison of DSI across Three Conditions in the Female Group

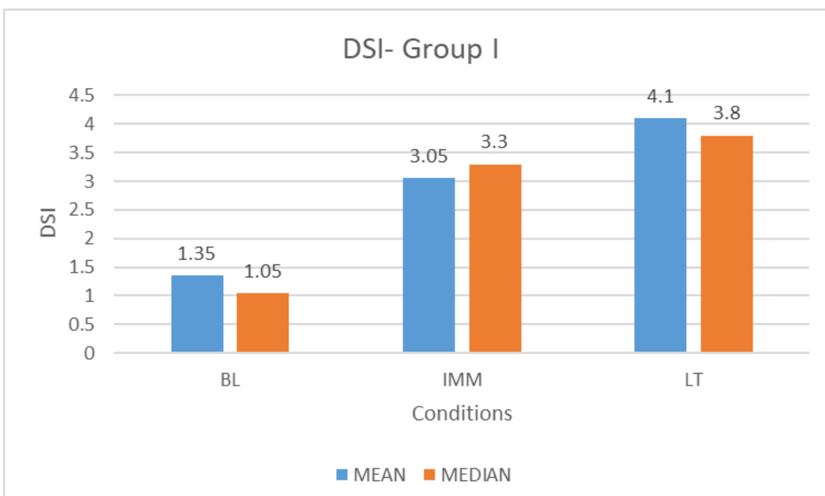

Figure 4.10.b

Comparison of DSI across Three Conditions in the Male Group

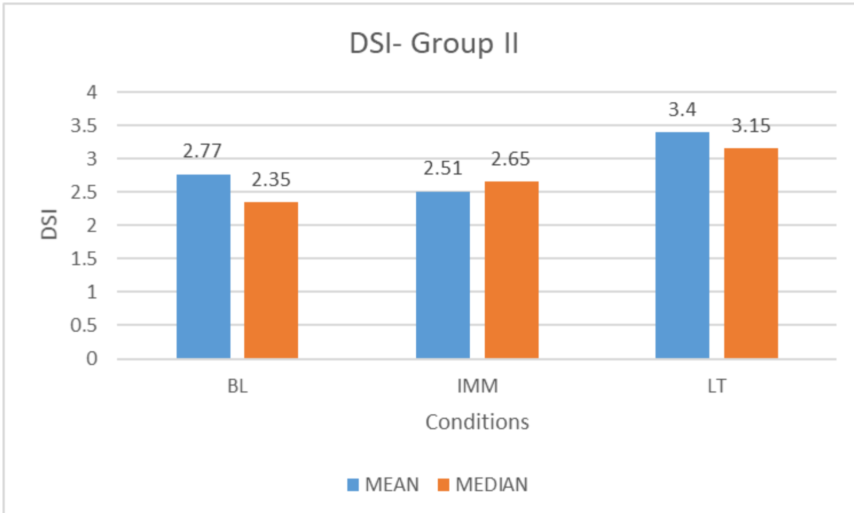

Figure 4.10.a revealed that DSI showed an increment in the immediate (mean: 3.05; median: 3.30) and the long term conditions (mean: 4.10; median: 3.80) when compared to the baseline condition (mean: 1.35; median: 1.05) in the female group. Figure 4.10.b showed that there was no such increment observed in DSI across the three conditions in the male group. DSI did not change across the three conditions in the male group. Friedman's test was used due to larger standard deviation, and the results revealed that there was a statistically significant difference seen in DSI across the three conditions for group I ($p<0.05$), and no statistical significance was seen across the three conditions for group II ($p>0.05$). Pair-wise comparison was done using the Wilcoxon signed-rank test for the female group, and the results showed that there is a statistically significant difference seen between the baseline and immediate conditions ($p>0.05$); immediate and long term ($p<0.05$);and also between baseline and long term ($p<0.05$) conditions. DSI was significantly better in the immediate and long term conditions when compared to the

baseline condition in the female group. Results from the Wilcoxon signed-rank test is presented in table 4.11

Table 4.11

Results of the Wilcoxon Signed-rank Test for DSI in Group I (Females)

Parameter	**Conditions**	**Group I**	
		/Z/	p
DSI	BL-IMM	2.67	0.00*
	BL-LT	3.69	0.00*
	IMM-LT	2.22	0.02*

(* indicates significance at 0.05 level)

4.4 Effects of Gender

One way MANOVA and Mann-Whitney test was administered to investigate the effect of gender across the three conditions on the measured parameters. One way MANOVA was done across the three conditions separately as few of the parameters were not normally distributed.

Effects of Gender in the Baseline Condition

One way MANOVA was used to test the significance between the two groups on the parameters such as sp F0, min F0, max F0, F0r, min I0, max I0, I0r, and MPT in the baseline condition. For Jitter and DSI, Mann- Whitney U test was used. The results revealed that sp F0, min F0, max F0, F0r, and min I0 are significantly higher in the female group when compared to the male group in the baseline condition. The other parameters such as max I0, I0r, and MPT are significantly higher in the male group when compared to the female group. No statistical significance is observed for jitter and DSI between the groups. The result from the tests of between-subject effect is presented in table 4.12.

Effects of Gender in the Immediate Condition

One way MANOVA was used to test the significance between the two groups on the following parameters: sp F0, min F0, F0r, min I0, I0r, MPT, and DSI in the immediate condition. For the other parameters such as max F0, max I0, and jitter, the Mann- Whitney U test was used. The results revealed that sp F0, min F0, max F0, and F0rare significantly higher in the female group when compared to the male group in the immediate condition. No statistical significance is observed for the other parameters such as min I0, max I0, I0r, MPT, jitter, and DSI. The result from the tests of between-subject effects is presented in table 4.12.

Effects of Gender in the Long Term Condition

One way MANOVA was used to test the significance between the two groups on the following parameters: min F0, max F0, F0r, max I0, I0r, MPT, and DSI. For the other parameters such as sp F0, min I0, and jitter, the Mann-Whitney U test was used. The results revealed that sp F0, min F0, max F0, and F0r are significantly higher in the female group when compared to the male group in the long term condition. No statistical significance is observed for the other parameters such as min I0, max I0, I0r, MPT, jitter, and DSI. The result from the tests of between-subject effects is presented in table 4.12.

Table 4.12

Results of the Between Group Comparison on Voice Parameters at Three Conditions

	Baseline		Immediate		Long term	
Parameters	F	p-value	F	p-value	F	p-value
spF0	307.269	0.000*	257.488	0.000*	-5.411	0.000*
minF0	110.641	0.000*	54.463	0.000*	25.680	0.000*
maxF0	58.842	0.000*	-5.009	0.000*	33.899	0.000*
F0r	18.441	0.000*	14.631	0.000*	22.156	0.000*
minI0	7.604	0.009*	0.183	0.671	-1.213	0.225
maxI0	7.277	0.010*	-1.804	0.071	3.506	0.069
I0r	14.940	0.000*	2.289	0.139	1.531	0.224
MPT	8.948	0.005*	2.240	0.143	4.948	0.032
Jitt	-0.922	0.357	-0.122	0.903	-1.761	0.078
DSI	-1.880	0.060	1.142	0.292	2.532	0.120

To summaries, Shapiro Wilk's test was carried out to explore the normality distribution among the data. Hence, one way repeated measures ANOVA and the Friedman test were used to compare the effect of lip trill exercise among three conditions for the parameters. Bonferroni pairwise comparison and Wilcoxon signed-rank test were done to investigate the significance between any of the two conditions (BL vs IMM; IMM vs LT; BL vs LT). One-way MANOVA and the Mann-Whitney test were used to investigate the gender effect. In group I (females), SpF0, Max F0, F0r, I0r, MPT and DSI were significantly increased in the both immediate and the long term conditions; Min F0 and Min I0 were significantly decreased after a week of home training and no statistical significance was seen for jitter parameter in the both immediate and the long term conditions. In group II (males), SpF0 was significantly increased in the immediate condition. Max F0 and F0r were significantly increased in the both immediate and the long term conditions; MPT was significantly increased after a week of home training and statistical significance were not observed for intensity parameters in VRP, Jitter and DSI measurements in the both immediate and the long term conditions. The frequency-related parameters such as SpF0, Min F0, Max F0 and F0 range were significantly higher in females when compared to males in all the three conditions. Intensity parameters and MPT were significantly higher in males when compared to females before the exercise, whereas no significant gender difference was seen in those parameters in the immediate and the long term condition. The results from the present study showed that the lip trill exercise had a significant immediate and long term effect on both female and male groups. The lip trill exercise has significantly altered the SpF0, VRP parameters and MPT in both immediate conditions and after a week of home training (long-term effect).

Chapter V

Discussion

The primary purpose of the study is to examine the immediate and long term effect of the lip trill, a SOVT exercise on acoustic and aerodynamic parameters in phononormic individuals. The principle objectives considered were to compare the immediate and long term effect of lip trill exercise from the baseline measurement and to explore the gender effect in three conditions (i) Baseline (BL), (ii) Immediate (IMM), and (iii) long term (LT) conditions. Comparison of the three conditions was determined using one way repeated measures ANOVA and Friedman test. The gender effect was determined by using the one-way MANOVA and Mann Whitney test. The results from the present study showed that the lip trill exercise had a significant immediate and long term effect on both female and male groups. The lip trill exercise has significantly altered the SpF0, VRP parameters and MPT in both immediate conditions and after a week of home training (long-term effect). It can be noted that VRP measures are: (i) min F0, (ii) max F0, (iii) F0 range, (iv) min I0, (v) max I0 and (vi) I0 range. The findings from this study are in accordance with the results of Brockmann-Bauser et al. (2019)where they reported that SpF0, F0 range, Max I0 and I0 range were significantly increased immediately after the lip trill exercise in the female group.

The results from the present findings also indicated that there is a significant gender effect seen on the voice parameters such as SpF0, VRP and MPT during the three conditions. The results and the conclusions based on the analysis are discussed under the following subheadings.

5.1 Immediate and long term effect of lip trill exercise on speaking F0 and VRP

5.2 Immediate and long term effect of lip trill exercise on MPT

5.3 Immediate and long term effect of lip trill exercise on Jitter and DSI

5.4 Gender effect

5.1 Immediate and Long Term Effect of Lip Trill Exercise on Speaking F0 and VRP

Speaking F0 was significantly increased in both males and females immediately after the lip exercise. The value of speaking F0 was significantly decreased after a week of home training and returned equivalent to the baseline value. This significance in spF0 immediately following the lip trill exercise suggested that the exercise acted as a vocal warm-up by increasing the tonus of the vocal fold. Similarly, Mezzedimi et al. (2020) found a significant increment in F0 immediately following the vocal warm-up exercise (lip trills and tongue trills) and a significant decrease in F0 was seen after the cool down exercise (descending scales, glides; yawning and sighing and vocal fry). In the present study also, the spF0 returned near to the baseline value which indicated that the lip trill exercise acted initially as a vocal warm-up and resulted in optimized vocal function after a week of continuous training (Mezzedimi et al., 2020). The obtained results was also supported by the findings of Onofre et al. (2017) study where they stated that the value of F0 was increased in choir singers after vocal warm-up followed by singing task.

The VRP parameters considered were: (i) min F0, (ii) max F0, (iii) F0 range, (iv) min I0, (v) max I0 and (vi) I0 range. In the female group, a significant betterment was seen in overall voice range both immediately and after a week of home training. In the male group, a significant improvement was seen only in Max F0 and F0 range in both conditions. However, there was an increment seen in I0 range after a week of home training in the male group, although the value is not significant. The long term training of lip trill exercise resulted in significantly greater overall intensity range in females. This is in agreement with the findings of Meerschman et al. (2017) study which stated that I0 range was significantly increased after six weeks of training on SOVTE in speech-language pathologists. The obtained results from the present study attributed that lip trill exercise resulted in increased vocal performance for both male and female groups. This finding is in concordance with research done by Van Lierde et al. (2011). The findings suggested that a combined vocal warm-up exercise which also included SOVTE resulted in significant improvement in the fundamental frequency and voice range in female speech-language pathologists(Van Lierde et al., 2011). Improved frequency and intensity parameters were associated with better vocal tonus and subglottal pressure (Brockmann-Bauser et al., 2018; Mendes et al., 2003). Thus, the findings from this study suggested that lip trill exercise had a positive impact on vocal quality by increasing the adaptation and regulation of vocal folds in both immediate conditions and after a week of home training.

5.2 Immediate and Long Term Effect of Lip Trill Exercise on MPT

In the present study, there was a significant improvement in MPT observed in the immediate and long term conditions for both groups. MPT was significantly increased immediately after the lip trill exercise, and it was maintained after a week of home training in females. Whereas, in the male group, the significance was seen only after a week of practice. MPT is a clinically reliable aerodynamic measurement tool which is used to assess the coordination between phonation and respiration and to assess the glottis efficiency (Christmann et al., 2013). This finding is in consonance with a result of Brockmann-Bauser et al. (2019)who reported that MPT was increased immediately after the lip trill exercise, although it is not significant. The SOVT exercise results in better vocal tract impedance by matching the impedance between the vocal fold and the tract, which in turn led the energy back to the glottis resulting in improved glottis efficiency (Titze, 2006; Titze & Story, 1997). Further, the significant increase in MPT signified better respiratory control in the participants after SOVTE (straw phonation) (Leite et al., 2018) and SOVTE also resulted in significantly increased expiratory lung pressure after six sessions of training (Kaneko et al., 2019).

5.3 Immediate and Long Term Effect of Lip Trill Exercise on Jitter and DSI

In the present study, Lip trill exercise did not have any significant effect on jitter in both immediately and after one week of home training for males and females. One possible reason could be due to larger variability between and within the subjects on acoustic measurements (Brockmann-Bauser et al., 2019; Dargin & Searl, 2015; Guzman et al., 2017). In the present study also, larger variability was observed for jitter parameter among the participants owing to larger standard deviation. However, DSI value was significantly better after immediate and long term practice of lip trill exercise in females. Increment in the DSI value after SOVTE contributed to the improved voice quality. Increase in DSI was achieved through increased tone and higher subglottal pressure as a result of SOVTE. This finding is in agreement with the results of Meerschman et al. (2019) who reported that straw phonation and lip trill resulted in significant improvement in DSI value after 3 weeks of training in dysphonic population. Furthermore, Van Lierde et al. (2011) found that vocal warm-up exercise, which included SOVTE, resulted in better DSI in female speech-language pathologists. Compared to the previous studies, the present study found a positive effect on DSI value by lip trill exercise, which was regularly practised over a week duration as against three week period.

5.4 Gender Effect

The frequency related measures such as SpF0, Min F0, Max F0 and F0 range were significantly higher in females when compared to males in all the three conditions. The increase in frequency parameters is due to the anatomical and physiological differences in the larynx between males and females. Due to the relatively shorter length of the vocal folds, the number of vibrations is greater which is resulted in higher F0 in females. The resulted findings are in congruence with the results of Sussman & Sapienza (1994) and De Felippe et al. (2006) studies where they found that female population had a significantly higher F0 while comparing to the male population. Another research finding also reported significantly higher F0 in females when compared to males (Sanchez et al., 2014) owing to the anatomical difference of the phonatory system.

Another interesting finding was intensity parameters and MPT were significantly better in males when compared to females before the exercise, whereas no significant gender difference was seen in those parameters in the immediate and the long term condition. This finding suggested that lip trill exercise had a significant impact on the intensity related measures and MPT in the female group. No significant gender effect was seen in other parameters such as jitter and DSI. Other studies on the gender effect in jitter measures were also in consonance with the present findings (De Felippe et al., 2006;

Sussman & Sapienza, 1994). One possible reason for no gender effect on DSI might be due to counteraction between the two parameters, i.e. Max F0 which is higher in females and MPT which is higher in males, and that had nullified the gender-specific acoustic markers in DSI (Wuyts et al., 2000). Besides, other similar studies also reported that no significant gender effect was seen in DSI values(BarstiesLatoszek et al., 2019; Kim et al., 2019).

Chapter VI

Summary and Conclusions

Voice disorders arise when the pitch, loudness or quality of an individual's voice has deviated from the standard range, or it is perceived as inappropriate in terms of speaker's age and gender (Boone et al., 2014). Voice disorders can result in a severe impact on the quality of life, and hence adequate training should be undertaken. Voice rehabilitation has given rise to various therapeutic approaches to treat the disordered voice and to improve the normal voice. These approaches are classified as hygienic, symptomatic, psychogenic, physiologic, and eclectic (Stemple & Hapner, 2018). One of the physiologic voice therapy approaches is semi occluded vocal tract exercise (SOVTE). SOVTE has been widely incorporated as a therapeutic approach to treat voice disorders and to train professional voice users. The effect of SOVTE have been investigated through different measures such as CT scan (Guzman et al., 2013), Electroglottographic measures (Andrade et al., 2014; Dargin & Searl, 2015; Guzman et al., 2018) and other multiparametric measures (Brockmann-Bauser et al., 2019; Meerschman et al., 2019) and it was proved to be resulting in increased vocal efficiency and better voice quality. There are different types of SOVTE ranged from higher to lower resistance. SOVTEs with high resistance such as phonating through a straw provide greater occlusion in the vocal tract; however, it is considered as more artificial. SOVTEs with low resistance such as sustaining high vowels provide less occlusion in the vocal tract, but it is natural (Rosenberg, 2014). Lip trill exercise is one of the SOVTE which is widely used in the clinical context offers better occlusion in the vocal tract and relatively less artificial when compared to phonation in a tube (Rosenberg, 2014). Several researchers have reported that lip trill exercise resulted in enhancing the voice quality in individuals by promoting vocal economy (Brockmann-Bauser et al., 2019; Gaskill & Erickson, 2008; Nam et al., 2019). However, there is a dearth of literature on the investigation of lip trill effects in the Indian population. Furthermore, only two studies till date have quoted the long term effect of SOVTE in vocally healthy individuals and dysphonic population (Guzman et al., 2018; Vimal, 2016). Comparison of the immediate and long term impact of SOVTE can help in calculating how much training is required to transfer the immediate effects to optimal vocal function, which aids in selecting a suitable treatment regimen. Hence, the present study made an attempt to investigate the immediate and long term effect of a semi occluded vocal tract exercise with a secondary source of vibration, lip trills on voice parameters in phononormic individuals. The principle objectives considered were to compare the immediate and long term effect of lip trill exercise on voice from the baseline measurement and to explore the gender effect in three conditions (i) Baseline (BL), (ii) Immediate (IMM), and (iii) long term (LT) conditions.

The present study included 40 phononormal participants in the age range of 18-25 years who were categorized into two groups based on gender. Group I contained 20 females and group II contained 20 males. The procedure involved acoustic and aerodynamic measurements of voice under three conditions: (i) Condition I (Baseline measurement); (ii) Condition II (Immediately after the lip trill exercise); and (iii) Condition III (after one week of home training). The acoustic and aerodynamic parameters considered were speaking fundamental frequency (sp F0), Voice Range Profile (VRP), Jitter (Jitt), Dysphonia Severity Index (DSI), and Maximum Phonation

Time (MPT). Speaking fundamental frequency was measured from PRAAT software (*version* 6.1.14). Voice Range Profile (VRP) and Dysphonia Severity Index were calculated using the lingWAVES software, (voice clinic suite pro from Wevosys, Germany, 2018) and the corresponding SPL meter- microphone. Jitter and Maximum Phonation Time were also obtained using the lingWAVES software while calculating the Dysphonia Severity Index. For Baseline measurement, spF0 was calculated using a counting task; VRP was obtained through phonating /a/ vowel at their lowest pitch to their highest pitch and from their loudest voice to their softest voice. Jitter, DSI and MPT were obtained through the sustained phonation task. After the baseline measurement, participants were instructed to perform the lip trill exercise, which consisted of 10 steps. Each lip trill steps had a specific time limit, and the total duration of the exercise was 3 minutes. After completion of 3 minutes of lip trill exercise (ten steps), post acoustic and aerodynamic measures were done immediately to calculate the immediate effect of lip trill exercise.

After the immediate post-exercise measurement, the participants were given home training and asked to follow the exercise one time in a day for a week. After one week, participants were called for post-one-week acoustic and aerodynamic voice recordings to investigate the benefits of long term lip trill exercise.

Shapiro Wilk's test was carried out to explore the normality distribution among the data. Hence, one way repeated measures ANOVA and the Friedman test were used to compare the effect of lip trill exercise among three conditions for the parameters. Bonferroni pairwise comparison and Wilcoxon signed-rank test were done to investigate the significance between any of the two conditions [baseline (BL) vs immediate (IMM);

IMM vs (long term) LT; BL vs LT]. One-way MANOVA and the Mann-Whitney test were used to investigate the gender effect. In group I (females), SpF0, Max F0, F0r, I0r, MPT and DSI were significantly increased in both immediate and the long term conditions; Min F0 and Min I0 were significantly decreased after a week of home training and no statistical significance was seen for jitter parameter in both immediate and the long term conditions. In group II (males), SpF0 was significantly increased in the immediate condition. Max F0 and F0r were significantly increased in both immediate and the long term conditions; MPT increased significantly after a week of home training and statistical significance was not observed for intensity parameters in VRP, jitter and DSI measurements in both immediate and the long term conditions. The frequency-related measures such as SpF0, Min F0, Max F0 and F0 range were significantly higher in females when compared to males in all the three conditions. Intensity parameters and MPT were significantly higher in males when compared to females before the exercise, whereas no significant gender difference was seen in those parameters in the immediate and the long term condition. The results of the present study showed that the lip trill exercise had a significant immediate and long term effect on both female and male groups. The lip trill exercise has significantly altered the SpF0, VRP parameters and MPT in both immediate condition and after a week of home training (long-term effect) condition.

The positive outcome obtained from the current study concluded that the SOVTE (lip trill) had a positive influence on the acoustic and aerodynamic measures both immediately and after a week of home training in both groups. The significant alterations in the measures as mentioned earlier revealed that the lip trill exercise aids in promoting better vocal competence by facilitating the interaction between the vocal tract and the glottal source.

Clinical Implications of the present study

The study has thrown a more in-depth perspective into the following;

- In comprehending the effect of SOVTEs particularly lip trill exercise of 3-minute duration have on voice production;

  The significantly improved aerodynamic and acoustic measures after the lip trill exercise on both conditions were associated with better vocal tonus and subglottal pressure (Brockmann-Bauser et al., 2018; Mendes et al., 2003). Thus, the findings from the present study suggested that lip trill exercise had a positive impact on vocal quality by increasing the adaptation and regulation of vocal folds in both immediate conditions and after a week of home training.

- In understanding the immediate and long term effect of lip trill exercise on voice measures.

  SOVTE had a pronounced effect on immediate as well as long term conditions. The outcome measures were significantly improved after a week of home training when compared to the immediate condition. This finding revealed that the immediate effect of the exercise might lead to a positive outcome in the long term when adequate training is given (Brockmann-Bauser et al., 2019; Guzman et al., 2018; Meerschman et al., 2019).

- In understanding the gender differences of lip trill exercises effect on voice production.

    The gender effect on the outcome measures was primarily due to the anatomical and physiological differences in the larynx between males and females. The absence of the gender effect in intensity related parameters and MPT after one week in training signified that the SOVTE (lip trill) had a significant impact in females by facilitating the better interaction between the source and the filter.

Limitations of the study and future directions

- The smaller sample size was used. Only 20 participants in each group have participated in the present study. Selecting a larger sample in the future can be helpful in generalizing the results.
- The present study was done only on phononormals. Hence, the results of this study have to be generalized cautiously across various voice disorders. Replicating the study with various voice disorders in the future might provide a better picture in comprehending the effect of lip trill exercise and its impact on various disorders.
- The effect size was not calculated in the present study
- A limited age range of participants was selected in the present study. Including participants in different age groups in both males and females in future might help to know and understand the age and gender interaction on the effect of lip trill exercises.

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