



Original Research Article

Immediate effects of “Ujjayi Pranayama” on aerodynamic, acoustic and self perception parameters of voice in professional voice users



M. Usha ^{a, b}, Jayashree S. Bhat ^{a, b, *}, B. Radish Kumar ^{a, b}, Gagan Bajaj ^{a, b},
P. Poovitha Shruthi ^{b, c}

^a Dept of Audiology and Speech Language Pathology, Kasturba Medical College, Mangalore, India

^b Manipal Academy of Higher Education, Manipal, India

^c Centre for Integrative Medicine and Research (Yoga), Manipal, India

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ABSTRACT

Background: Voice plays a major role in communication, and it reveals the speaker's physical and emotional health, personality, and identity. Professional voice users are dependent on their voice for their livelihood. A minimal change or deviation in their voice can interfere with their career. Since respiration is the source for voice production, good lung capacity and the inspiratory-expiratory ratio are very important in maintaining a good voice quality. *Ujjayi Pranayama*, an effective breathing technique is targeted in this study.

Objective: To investigate the immediate effects of *Ujjayi pranayama* on acoustic, aerodynamic and self-perception parameters of voice in professional voice users.

Method: Twenty normophonic female teachers performed this breathing technique taught by yoga professional. Parameters of aerodynamic, acoustic, and self-perception were analyzed at pre and post-practice. **Results:** Significant differences in the acoustic variables including intensity and jitter were observed. Aerodynamic parameters have shown significant improvements in the variables including Maximum phonation Duration (MPD), Estimated Subglottal Pressure (ESGP), Laryngeal Conductance (LAC), Laryngeal Resistance (LAR) and Sound Pressure Level (SPL). Among the study participants, 80% have rated the *Ujjayi pranayama* as useful in prepping their voice for the vocal loading tasks.

Conclusion: In view of the better objective evidence and significant improvements in the study variables including the participant's self-perception, authors suggest that *Ujjayi pranayama* can also be used in voice rehabilitation as a vocal warm-up exercise.

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1. Introduction

Yoga, having its root in the Indian culture and philosophy, is considered as an ancient art involving the physical movement. It is believed to be crucial for achieving both physical and mental well-being, as well as a means for energising and strengthening the physical elements in human body. *Yoga* is one among 6 systems (Nyaya, Vaisheshika, Samkhya, Yoga, Purva mimamsa and Uttara mimamsa) of Hindu philosophy and it deals with the physical exercise and well-being. *Pranayama* is embedded in yoga and is practiced

simultaneously. *Pranayama* is considered as control or restraint of energy in one's body [1]. *Pranayama* consists of various breathing techniques to control the vital energy by performing specific breathing exercises and regulating the breath to proper channels [2].

Researchers have reported several health benefits of practicing *pranayama* on a regular basis. An interventional study which assessed the benefits of *pranayama* in spinal cord injury patients at the hospital for 15 days has reported the beneficial effects of *pranayama* in terms of increase in lung functioning abilities [3]. Patients (20–30 years of age) of both genders with traumatic thoracic spinal cord injury received three types of breathing techniques such as *Om* chanting, *Anulomvilom pranayama*, and *Bhramari pranayama* as intervention every day for a duration of 15 days. The results revealed improved spirometer values for all the aerodynamic parameters. *Pranayama* along with *yoga* and meditation are scientifically proven

* Corresponding author.

E-mail address: bhat.js@manipal.edu

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to be beneficial for many conditions [2]. The high frequency yogic breathing for the patients with asthma, wherein they were asked to perform *kapalabathi* (skull shining breathing) breathing technique in 1 Hz have established significant changes in their pulmonary functioning [4]. Another breathing technique named *Bhramari* (humming bee breath) have gained importance in the field due to its effective control on blood pressure and heart rate [5,6]. It also brings relaxation, reduces anxiety and stress, and improves conditions of ear, nose, throat, and sinus. Humming bee breathing technique has proved to be effective in changing the cardiovascular parameters and pulmonary functions [6–10]. Authors have previously reported that humming bee breathing practice resulted in changes in acoustic and aerodynamic parameters of voice, as well as giving a fine resonant voice quality [11].

Ujjayi pranayama (UP) or Ocean breathing or victorious breathing has been identified to have many health benefits. *Ujjayi* is a conjoined Sanskrit term that include “ud” meaning a sense of superior or the power, and “jaya” is victory, success or conquest, giving it a meaning of superior victorious breath [12,13]. Due to ocean wave like sound production during inhalation and exhalation, it is popularly known as ocean breathing technique.

UP is either practiced alone or in combination with few other breathing types in an intervention program. Sheethal et al., in 2012 have reported improvement of respiratory system and the positive physiological benefits by practicing *pranayama* and UP was a part of *pranamayama* regime. Results have shown improved maximal ventilation, vital capacity, and peak expiratory flow rate in participants with three months of practice [14]. UP is reported to mitigate the cardiovascular changes due to stress and anxiety by restoring the cardiovascular autonomic balance [13]. If this technique is practiced along with *Sudharshana kriya*, which is another breathing pattern, it works as an antidepressant and can be used on alcohol dependent individuals [13].

Apart from having health benefits, *pranayama* also improves the quality of voice [11] by giving voice a soothing, powerful, and melodious texture [15]. Voice production involves various sub-systems, respiratory system being the major one. Professional voice users like singers, teachers, actors, have high prevalence and are at increased risk of developing voice disorders due to their continuous vocal demand and usage (20,22). Voice rehabilitation comprises of various techniques from warm-up to cool down exercises, deep breathing techniques, relaxation exercises, resonant voice therapy, semi-occluded vocal tract exercise, pitch glides, and relaxed sigh. All these techniques are used in combinations and the efficacy of this combination have been reported by the authors (1,23). A speech language pathologist who is also a yoga teacher has proved benefits of modified *yoga* along with traditional voice therapy in individuals with muscle tension dysphonia [16]. Nagendra et al., in 2014, have listed few postures in *yoga* and specific breathing techniques in *pranayama* which are useful in disciplining the functional voice disorders in professional voice users [17]. Similarly Hutton (2014) has reported benefits of different postural alignments along with breathing techniques and hand gestures (*mudras*) and meditation, in improving the health, performance anxiety, and voice quality in singing teachers [18].

1.1. Need for the study

Voice is the major and an important aspect for professional voice users. It is not always feasible to give the intervention once the damage has been done; instead, the professional voice users need awareness and tools for the prevention of vocal damage. Scientific evidences are reported on improving lung capacities in few health conditions such as asthma and pulmonary disorders, and also in reducing stress, anxiety, controlling the blood pressure

and cardiovascular parameters by practicing UP. Along with this, UP also has an effect on throat by correcting the “*Vishuddhi chakra*” or “Energy concentration in throat” and it improves the diaphragmatic breathing [19]. This breathing helps in correcting the breathing pattern and improving pulmonary function, the main source for voicing. Hence, it can be hypothesized that UP can bring change in the quality of voice in professional voice users with or without laryngeal pathology. It is possible to find scientific evidence on changes or improvements in respiration and other aspects by practicing UP. Similarly, focus on how this practice can bring changes with respect to quality of voice, acoustic, aerodynamic or at perceptual level, the literature is very limited. Hence the current study aims to bring out the scientific evidences for improvement in voice and its quality through practicing UP by analysing the acoustic, aerodynamic and self-perception in normophonic female participants who are involved in teaching children.

2. Method

2.1. Participants and design

The study design of pre-test post-test included 20 female graduates who were involved in teaching for minimum of 3 years. The current study was approved by Institutional Ethics Committee, Kasturba Medical College, Mangaluru. All the participants were within the age range of 20–25 years (Mean age: 26.92 ± 1.18 years). Since majority of the teaching professionals were females, as a preliminary attempt, only female participants were considered in the study with a simple random sampling. Informed consent was obtained from all the participants and study information were explained before recruiting them. Informal questionnaire was administered to collect their demographic data. Inclusion criteria for participation were hearing sensitivity within normal limits, a minimum 3 years of teaching experience, and teachers who feel their voice quality is changing or has changed gradually due to their profession. Exclusion criterion included participants to be non-yoga practitioners, and without any formal training in yogic practice. Exclusion criterion also involved ruling out the history of laryngeal pathology, asthma, allergies, respiratory tract infections, intake of alcohol, smoking and oral contraceptives. It was ensured that the data was collected between 5th to 15th day of their menstrual cycle [11].

2.2. Instrumentation

- Acoustical voice recordings were carried out in praat software installed in a HP laptop and Sennheiser headphones with microphone was used for recording the voice.
- Aerodynamic parameters were recorded and analyzed using pre-calibrated Aeroview System (Glottal enterprises, version 1.7.0). This system consists of a silicon oro-nasal mask, to which airflow and pressure transducers are connected. When the pressure consonant is produced, these transducers pick up the airflow and pressure signals.
- Handheld portable spirometer was used to measure the lung capacities.

2.3. Ujjayi pranayama intervention

A certified yoga practitioner and also a Speech Language Pathologist by profession taught the procedure of performing UP by demonstrating it to every participant on one–on–one interactive sessions. Participants were addressed individually, for correcting their breathing pattern and sitting posture. All the participants were instructed to sit straight in a relaxed manner, to distribute the entire

body weight equally on the chair, to keep the knees bent at right angle, upper body perpendicular to the thighs, the foot flat on the ground, and arms rested on the thighs [20]. Researcher ensured a minimum of 3 hours of gap from the session to their previous food intake [15]. All the participants were educated on the movement of the abdomen, which gets contracted during exhalation and released during inhalation throughout the exercise. They were also instructed to keep the neck and shoulder relaxed and the entire upper body calm, by not getting strained or keeping it rigid [21].

For every participant, UP procedure was explained initially followed by demonstration of the same by the researcher. Three trials were given to each of the participants, monitored by the researcher. They were asked to perform deep breathing by maintaining an equal ratio between inhalation and exhalation. While inhaling and exhaling they were instructed to make a specific sound in their throat which would resemble a sound of an ocean wave. This can be achieved by constricting the back of the throat a bit, without straining the neck region, and inhale by constricting the throat and letting the air pass through the glottis with an ocean wave sound and exhale. During this process there will be slight constriction the glottis muscle along with the epiglottis (17,28). Once this was achieved, all the participants were instructed to perform this breathing for 12 cycles of 3 sets, giving a minute break between each set [11].

2.4. Procedure

Every participant underwent pre-recording of acoustic and aerodynamic parameters 3 hours after their breakfast in the morning. Immediately after the pre-recording, they were explained and trained to perform the UP. All of them had to perform in three sets, with 12 cycles of UP in each set. Since the study was to find the immediate effects of UP on voice, post recordings were done immediately after performing the UP, using the same protocol adopted for the pre-recording. During post recording, self-perception of their voice was rated by all the participants. This was a 4 point rating scale, 0 being – No difference, 1 – Easier voice, 2 – Better voice, 3 – Easier and Better voice [22]. This self-perception scale was based on ease of phonation or no strain, the effort felt while producing the voice was considered as easier voice. If there was any positive perceived change in voice quality, it was considered as better voice. If both the effects were seen, then rating was easy and better voice.

The voice samples were recorded pre- and post-performance of UP in a sound treated voice laboratory. All the participants were instructed to phonate a sustained vowel of /a/, /i/, and /u/ as long as possible in their comfortable pitch and loudness. During every recording, three trails were collected and the best trial was used for the acoustic analysis of voice. This recording was done using praat software (freely downloadable) in HP laptop. In the same set up, UP was taught and performed by all the participants.

For the aerodynamic recordings, Aeroview silicon oro-nasal mask was given to the participants to hold and keep it on the face as instructed by the researcher. Once the proper seal was achieved, participants were asked to produce the pressure consonant/pa/, at a comfortable rate. Also, handheld portable spirometer was attached to the disposable mouthpiece and the participants were instructed to take a deep breath and blow air into the mouth piece as forcefully as possible. For all these recording, three trials were taken for both pre- and post-sessions.

2.5. Acoustic and aerodynamic analysis

Three trials each of all sustained phonation were recorded as voice samples before and after practicing UP using praat software. Among the three trails of voice sample which were recorded, best

Table 1
Mean, standard deviation, and paired t test of acoustical parameters for all the participants before and after Ujjayi pranayama.

	Mean		SD		p
	Pre	Post	Pre	Post	
F0 (Hz)	191.73	198.12	46.32	42.55	0.236
I0 (dB)	63.23	68.67	4.14	3.37	0.000 ^a
F1 (Hz)	692.29	663.69	124.84	128.77	0.377
F2 (Hz)	1376.19	1316.75	179.66	181.96	0.338
F3 (Hz)	2734.09	2564.30	291.20	231.32	0.051
F4 (Hz)	3932.60	3897.32	302.13	238.04	0.642
Jitter (%)	0.75	0.38	0.58	0.20	0.019 ^a
Shimmer (%)	5.95	2.10	8.85	0.74	0.062
NHR	0.057	0.028	0.07	0.016	0.080

F0 – Fundamental Frequency, F1-4 - Formant frequencies, NHR – Noise-to-Harmonic Ratio.

^a Significant results with P value less than 0.05.

sample was used for the analysis. Using the same software, middle stable 10 s of the phonation sample /a/ was used to analyse the acoustic parameters like fundamental frequency (F0), intensity (I0), formant frequencies (F1, F2, F3 and F4), perturbation parameters like shimmer and jitter, and Noise to Harmonic Ration (NHR).

Maximum Phonation Duration (MPD) of /a/, /i/, and /u/ were calculated by taking the best of the three trails. Recordings of continuous three syllables of pressure consonant /pa/ were selected for the analysis of aerodynamic parameters like Estimated Sub-glottal Pressure (ESGP), Glottal Mean Airflow Rate (MAFR), Laryngeal Resistance (LAR), and Laryngeal Conductance (LAC) in aeroview software, where the software algorithm gives the values of all these mentioned parameters. Other aerodynamic parameters like Forced Expiratory Volume (FEV), Forced Vital Capacity (FVC), and Peak Expiratory Flow (PEF) which were recorded in handheld spirometer, were taken and tabulated directly from the spirometer.

2.6. Statistical analysis

Statistical Package for Social Sciences (SPSS), version 16.0, a freely downloadable software by IBM SPSS statistics was used to conduct the statistical analysis. Mean and standard deviation were obtained for the acoustic and aerodynamic data of all the participants' recorded pre- and post-UP technique. Shapiro-Wilk normality distribution was performed for the data to see the significant difference between pre- and post-recordings, paired t-test was conducted by keeping the p-value level of significance as 0.05. Mode was calculated for the 4-point self-perception rating scale.

3. Results

3.1. Acoustic measures

Mean and standard deviation for the acoustic variables like fundamental frequency, intensity, all four formant frequencies, shimmer, jitter and noise to harmonic ratio of pre- and post-UP task are tabulated in Table 1 for all the 20 participants with the mean

Table 2
Mean, standard deviation, and Paired t test of Maximum Phonation Duration for all the participants before and after Ujjayi pranayama.

	Mean		SD		p
	Pre	Post	Pre	Post	
/a/ (Secs)	6.92	9.84	1.40	2.22	0.000 ^a
/i/ (Secs)	7.12	10.75	1.54	2.05	0.000 ^a
/u/ (Secs)	7.43	10.50	10.43	1.89	0.000 ^a

^a Significant results with P value less than 0.05.

age of 26.92 ± 1.18 years. Mean scores of fundamental frequency and intensity increased from pre to post, whereas for the rest of the acoustic variables mean scores decreased. Paired t-test showed significant difference in the parameter's intensity and jitter.

3.2. Aerodynamic measures

Table 2 summarizes the mean and standard deviation along with significant difference in all three phonation samples of maximum phonation duration before and after practicing UP. There was a significant difference observed between pre- and post-recording.

Phonatory aeroview parameters and its mean and standard deviation are tabulated in Table 3. Mean values of Estimated subglottal pressure and laryngeal resistance decreased after the UP, whereas the mean airflow rate, laryngeal conductance and sound pressure level increased mean scores in the post UP recordings. Paired t-test showed significant difference between pre- and post-recording for all the parameters except for mean air flow rate.

Mean and standard deviation of spirometric values are listed in Table 4, in which paired t-test showed significant differences between all three variables: forced expiratory volume, forced vital capacity and peak expiratory flow, before and after the practice of UP.

3.3. Self-perception rating analysis

Ratings of self-perception were tabulated and the frequency for each of the parameter for all the participants was noted. Since, only post set of data was available for self-perception, no statistical tests could be performed. Fig. 1 shows the percentage of frequencies depicting the self-perception of individual's voice after practicing UP. Out of the 20 participants, 80% felt they had an easy and better voice, 10% felt easy voice, 5% with better voice and rest 5% had felt no difference in their voice after performing UP.

4. Discussion

Objective of this study was to assess the immediate effects of practicing *Ujjayi pranayama* on acoustic and aerodynamic variables of voice in a group of Normophonic female participants who were involved in teaching children. The information on self-perception about their voice after practicing this UP was also collected.

In this study, acoustic parameters improved in the post recording values. Mean values of fundamental frequency and intensity increased compared to pre practice of UP, and the increment in intensity had a significant difference. Similar trend was observed with the humming bee breathing or *Bhramari pranayama* [11], trained singers were able to control frequency and intensity parameters efficiently. Formant frequencies vary with the length of the vocal tract and with the source or the harmonics. Singers are known to ideally keep their larynx in a lowered and comfortable position, in order to avoid voice problem associated with the raised larynx. The formant frequencies studied in the singers with lowered larynx constitutes slightly reduced formant frequencies which represents the good harmonics and better quality of voice [23]. In the current study, there was decrease in the mean values of all the formant frequencies (F1, F2, F3 and F4) but statistically no significantly difference were seen in these formant frequencies. Reason for variation in the formant frequency could also be contributed to the changes in the source of voice production or glottal pressure or airflow; which is further explained with the aerodynamic results. There has been decrease in the perturbation variables i.e., jitter and shimmer in the post values indicating less rate of fluctuation in the frequency and intensity of the voice samples after practicing UP with a significant change in the jitter percentage. Yogic breathing or

Table 3

Mean, standard deviation, and Paired t test of aerodynamic measures for all the participants before and after Ujjayi pranayama.

	Mean		SD		p
	Pre	Post	Pre	Post	
ESGP (cmH2O)	8.13	5.05	1.77	1.20	0.000 ^a
MAFR (L/sec)	0.236	0.288	0.05	0.11	0.070
LAR	35.29	17.55	13.03	10.24	0.000 ^a
LAC	0.03	0.06	0.01	0.03	0.001 ^a
SPL (dB)	70.86	80.24	6.20	3.76	0.000 ^a

ESGP – Estimated Subglottal Pressure, MAFR – Mean AirFlow Rate, LAR – Laryngeal Resistance, LAC- Laryngeal Conductance, SPL – Sound Pressure Level.

^a Significant results with P value less than 0.05.

pranayama helps to channelize the breath and smooth airflow, along with getting a better voice quality, reflected objectively with the lowered perturbation parameters in the current study [11].

The difference in the mean values seen in the formant frequencies could be due to change in the source system of the voice production, which can be seen as the variations in the values of aerodynamic variables in this study. These variables have shown significant difference after practicing UP. Maximum phonation duration for all the vowels increased with a significant difference from pre to post values. This is in conjunction with the significant difference in increase of laryngeal conductance. For the laryngeal conductance to increase, there should be more airflow rate and the results have shown increased mean value of the mean air flow rate scores. With this increased laryngeal conductance, resistance decreases as it is inversely proportional. This is in adjunct with the significant decrease in the estimated subglottal pressure. Due to more airflow rate and laryngeal conductance, one can see significant increment in the sound pressure level as well. This trend of lower estimated subglottal pressure with increased laryngeal conductance and sound pressure level are in consensus with a similar study using a different intervention i.e. yogic breathing of humming bee exercise [11]. Also increase in the fundamental frequency is contributed to the changes happened in airflow measures as explained by Sundberg, in 2018 with respect to singers' voice [24]. There are evidences to prove UP brings improvement in pulmonary function by correcting the breathing pattern and by increasing the usage of lung capacity. UP encourages the deep breathing where air fills in the diaphragm and intercostal muscles and fills the lungs; with this one can take control of the rate of respiration with practice [14]. The pranayama, an exercise which encourages deep breathing, has effect on autonomic nervous system since this breathing provides good amount of oxygen to the body. Moreover it helps in controlling and coordinating between the lungs and central nervous system [25]. As the deep breathing happens, oxygen supply to the body increases which in turn stimulates the cardiovascular muscle and helps in controlling and reducing the heart and respiration rate along with blood pressure [13]. Also slow breathing will decrease the sympathetic activity and increase the parasympathetic activities compared to fast breathing [26].

Table 4

Mean, standard deviation, and Paired t test of aerodynamic measures for all the participants before and after Ujjayi pranayama.

	Mean		SD		p
	Pre	Post	Pre	Post	
FVC	1.47	3.46	0.60	1.42	0.000 ^a
FEV	1.43	3.24	0.72	1.61	0.000 ^a
PEF	1.39	3.49	0.59	1.40	0.000 ^a

FVC – Forced Vital Capacity, FEV – Forced Expiratory Volume, PEF – Peak Expiratory Flow.

^a Significant results with P value less than 0.05.

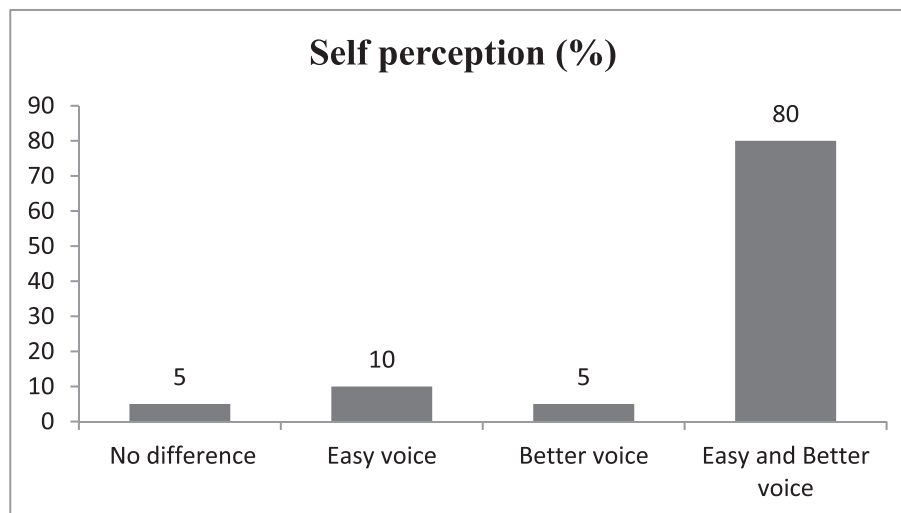


Fig. 1. Bar chart representing the percentage of self perception scores of all the participants.

There are warm-up exercises for voice rehabilitation, effective in bringing down the tension and rigidity of the muscles. UP warms up the inhaled air, because when we inhale, we constrict the back of the throat, epiglottis and glottis muscle by making a narrow passage for the airway, almost like a straw phonation. This results in very little amount of air to pass through the glottis to the lungs very slowly by creating ocean wave like noise. The air which gets bounced back due to constriction and the narrow path, remains in the nasal cavity and the body temperature makes the breath warmer compared to the outside temperature [27]. Even though there is no voicing involved, due to the constriction, noise is produced during both inhalation and exhalation. Hence, it is possible to apply this breathing technique in place of vocal warm-up exercises in voice rehabilitation. In terms of self-perception, only 5% of the participants voted it as having no difference in their voice after performing UP, but 10% rated it for improved ease of phonation after ocean breathing. 5% rated it as better voice and the rest 80% rated for easy and better voice, which means that there was ease of phonation along with better voice perception compared to the voice before practicing UP.

5. Conclusion

Current study was an initial attempt to investigate the immediate effects of *Ujjayi pranayama* on acoustic and aerodynamic variables along with self-perception of voice in normophonic female teachers. Results of the investigation has indicated significant differences in the acoustic variables such as intensity and jitter, along with decreased mean values of voice perturbations. Aerodynamic parameters have shown significant improvements in the following parameters: MPD, ESGP, LAC, LAR and SPL. 80% of the participants have rated *Ujjayi pranayama* technique as useful in prepping their voice by describing their voice as easy and better after performing *Ujjayi pranayama*. The study mainly focused on teachers and the immediate effects of UP on their voice quality at their comfortable pitch and loudness level. The authors would like to suggest to adopt *Ujjayi pranayama* as a vocal warm-up exercise for voice rehabilitation. Further investigation can be planned on the long-term effects of *Ujjayi pranayama* on voice, also in males as well as children, and in different vocal pathologies.

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Conflict of interest

None.

Author contributions

M. Usha: Conceptualization, Methodology, formal analysis, investigation, resources, data curation, writing – original draft; **Jayashree S. Bhat:** Conceptualization, Methodology, formal analysis, writing – review and edit, visualization, supervision, project administration, funding acquisition; **B. Radish Kumar:** Formal analysis, writing – review and edit, project administration, funding acquisition; **Gagan Bajaj:** Formal analysis, writing – review and edit, project administration, funding acquisition; **P. Poovitha Shruthi:** Validation, resources, funding acquisition.

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