# DEVELOPMENT OF A TOOL TO OBJECTIVELY IDENTIFY NORMAL HUMAN VOICE

A dissertation submitted For the Award of the Degree of

*Doctor of Philosophy (Medical)*

***Under The Faculty of Medicine***

**BLDE (Deemed to be University), Vijayapur Karnataka,**

By


**Dr. LATHADEVI HASSAN THOTAPPA**

Reg. No-11PhD007

PhD Research Scholar


Under the guidance of


**Dr. S.P. GUGGARIGOUDAR**

**BLDE (Deemed to be University)**

Department of **Otolaryngology and Head and Neck Surgery**

Shri B.M.Patil Medical College, Hospital & Research Centre,

Vijayapura, Karnataka


**2019**

# DECLARATION BY THE CANDIDATE

I hereby declare that declaration/ thesis entitled **"DEVELOPMENT OF A TOOL TO OBJECTIVELY IDENTIFY NORMAL HUMAN VOICE"** is a bonafide and genuine research work carried out by me under the guidance of **Dr. S.P. GUGGARIGOUDAR,** Department of **Otolaryngology and Head and Neck Surgery,** Shri B.M. Patil Medical College, Hospital & Research Centre, Vijayapura, Karnataka. No part of this thesis has been formed the basis for the award of any degree or fellowship previously.

Date:

Place: Vijayapura

Signature of the Candidate

**Dr. Lathadevi Hassan Thotappa**

11PhD007

# BLDE (Deemed to be University), Vijayapura Karnataka,

This is to certify that this thesis entitled "**DEVELOPMENT OF A TOOL TO OBJECTIVELY IDENTIFY NORMAL HUMAN VOICE**" is a bonafide and genuine research work carried out by **Dr. Lathadevi Hassan Thotappa** under our supervision and guidance in the Department of **Otolaryngology and Head and Neck Surgery BLDE (Deemed to be University),** Shri BM Patil Medical College, Hospital & Research Centre, Vijayapura, Karnataka in the fulfillment of the requirements for the degree of doctor of philosophy (Medical).


**Dr. S.P. Guggarigoudar**
Guide
Professor Department of otolaryngology and
Head and neck surgery,
Shri B. M. Patil Medical College, Hospital &Research
aCentre, Vijayapura, Karnataka)

**Dr. Lathadevi Hassan Thotappa**
Professor & HOD
Department of otolaryngology and
Head and neck surgery
Shri B. M. Patil Medical College,
Vijayapura, Karnataka

# BLDE (Deemed to be University), Vijayapura Karnataka,

## ENDORSEMENT BY THE PRINCIPAL/HEAD OF THE INSTITUTION

This is to certify that this thesis entitled **"DEVELOPMENT OF A TOOL TO OBJECTIVELY IDENTIFY NORMAL HUMAN VOICE"** is a bonafide and genuine research work carried out by **Dr. Lathadevi Hassan Thotappa** under our supervision and guidance in the Department of **Otolaryngology and Head and Neck Surgery BLDE (Deemed to be University),** Shri B.M. Patil Medical College, Hospital & Research Centre, Vijayapura, Karnataka in the fulfillment of the requirements for the degree of doctor of philosophy in Otolaryngology and Head and Neck Surgery (Medical).

**Date:** **Seal and Signature of Principal**

**Place: Vijayapura**

**Dr. Aravind V Patil.**

**B.L. D.E.(Deemed to be University),**

**SHRI B.M.PATIL MEDICAL COLLEGE, HOSPITAL AND RESEARCH CENTRE,**

## COPYRIGHT

## Declaration by the Candidate

I hereby declare that the BLDE University's Shri B.M.Patil Medical College, Hospital & Research Centre, Vijayapura, Karnataka, shall have all the right to preserve, use and disseminate this declaration/ thesis In print or electronic format for academic/research. BLDE(Deemed to be University), shri B.M.Patil Medical College, Hosptial and Research Center, Vijayapura, Karnataka.

**Date:**

**Place: Vijayapur**

Signature of the Candidate

**Dr. Lathadevi Hassan Thotappa**

**Dr. S.P. Guggarigoudar**

Guide

Professor Department of otolaryngology and Head and neck surgery, Hospital &Research Centre Vijayapura, Karnataka)

# ACKNOWLEDGEMENT

Firstly, I express my sincere gratitude to my guide, **Dr S.P.Guggarigoudar,** Professor and Head, Department of Otolaryngology, Shri BM Patil Medical College, Hospital and Research Centre, Vijayapura, Karnataka for his masterly directions, constant support and eminent guidance, at every stage of this study. He has place d a full faith and undoubted trust in me which helped me a lot in carrying out my research work successfully.

I owe my most sincere gratitude to **Dr. M.S. Biradar, ViceChancellor** BLDE (Deemed to be University)for the help and support.

I owe my most sincere gratitude to **Dr. Aravind V. Patil,** Principal, ShriB.M. Patil Medical College, Hospital &Research Centre, for the help and support.

I owe my most sincere gratitude to **Dr.J.G Ambekar** Registrar, BLDE(Deemed to be University)and **Mr Satish Patil** Deputy Registrar ,BLDE (Deemed to be University)for the help and support.

I would like to express my very great appreciation to the Vice-principal, Shri B.M. Patil Medical College, Hospital & Research Centre **Dr Tejashwini Vallabha, and Dr. S.V.Patil,** Vice Principal (academics) for their support.

I express heartfelt thanks to all the **Members of PhD committee**, BLDE(Deemed to be University) for correcting my mistake throughout my tenure.

I am sincerely indebted to **Dr. Karadi R.N, for** Professor and former Head of the Department of Otolaryngology and Head and Neck Surgery, Shri B. M. Patil Medical College, Hospital & Research Centre, Vijayapura for his support

I would like to express my sincere gratitude to Mr. vijay Chopra, Principal, Sri BM Patil Institute of Nursing Sciences, Sri Yadrami, Former principal, KCP Science college, Vijayapura and Mrs Savita Patil, professor, computer sciences KCP

Sciences College, Vijayapura, Smt. Manjula, chief librarian and Mr. Shanwaz, Statistician of Shri B. M.Patil Medical College, Hospital & Research Centre, Vijayapura for their cooperation during the study.

I would like to extend my warm thanks to my Husband **Shri. Sachidananda Kumar,** my mother **Smt. Jayalakshmi,** daughter **Smt. Madhura HS**, Son in law, **Sri Rajesh Shivanand** and son **Manav,** without their support and help, I could not dedicate to research and it would have been extremely difficult for me to accomplish this thesis.

I wish to acknowledge the help provided by all my Teaching and non teaching staff of Department of Otolaryngology and Head and Neck surgery. I extend my special thanks to Dr. Shilpa Potnuru for assistance during my thesis.

I sincerely take an opportunity to acknowledge gratitude to all the people without whom this thesis would not have been possible.

**Dr. LATHADEVI HASSAN THOTAPPA**

Ethical Committee
BIJAPUR-586103
OUT WARD
IEC/29/2012
Date 02/01/12
Shri B.M. Patil Medical College

B.L.D.E. UNIVERSITY'S

SHRI.B.M.PATIL MEDICAL COLLEGE, BIJAPUR-586 103

INSTITUTIONAL ETHICAL COMMITTEE

# *INSTITUTIONAL ETHICAL CLEARANCE CERTIFICATE*

*The Ethical Committee of this college met on* 29-12-2011 *at* 10-30 am *to scrutinize the Synopsis/Research projects of postgraduate/undergraduate student/Faculty members of this college from Ethical Clearance point of view. After scrutiny the following original/corrected & revised version synopsis of the Thesis/Research project has been accorded Ethical Clearance.*

*Title* "Development of a tool to objectively identify normal human voice"

—x—x—x—

*Name of P.G./U.G. student/Faculty member* Dr. H.T. Lathadevi, Prof of otorhinolaryngology

*Name of Guide/Co-investigator Dr.* S.P. Guggarigoudar, Prof of otorhinolaryngology

DR.M.S.BIRADAR,
CHAIRMAN
INSTITUTIONAL ETHICAL COMMITTEE
BLDEU'S, SHRI.B.M.PATIL
MEDICAL COLLEGE, BIJAPUR.

Following documents were placed before E.C. for Scrutinization

1) Copy of Synopsis/Research project.
2) Copy of informed consent form
3) Any other relevant documents.

**Contents**

**INDEX - Figures & Illustrations**

**INDEX - Tables**

**ABSTRACT**

Acoustic analysis is used to assist differential diagnosis, documentation and evaluation of treatment for voice disorders. Clinical data has shown that Jitter, Shimmer, Mean Pitch and Harmonic Noise Ratio are the indices of voice pathology. A voice with some periodicity can now be analysed with a computerised acoustic analyser, a relatively newer technique that can be widely used in clinical practice.

*Objectives* : To create a database of normal voices, analyse and identify different parameters of these voices and hence identify benchmarks of normal voices.

*Materials and Methods* : Voice samples of 458 normal males and 542 normal females aged between 18 to 28 years were collected using a sustained vowel /a/ which was recorded and analysed using a freely downloadable software " PRAAT". The parameters like Jitter, Shimmer, Harmonic to Noise Ratio and Pitch were derived and mean, SD and range of voice parameters were calculated.

*Results* : In males the value of parameters were mean pitch(137.05), jitter(0.011), shimmer(0.08) and Harmonic to Noise Ratio(20.48). In females the parameters were mean pitch(234.27), jitter(0.01), shimmer(0.08) and harmonics to noise ratio(21.73).

*Conclusion* : Voices can be objectively analysed using acoustic parameters like mean pitch, jitter, shimmer and harmonic to noise ratio. A large database yields more reliable normative parameters. Institutions should develop their own standard protocol for selection of subjects, recording of voices and their analysis.

## INTRODUCTION

Voice is an acoustic output of the vibrations of the vocal folds and is the basic source for speech[1]. In contrast, speech is a meaningful acoustic output created by the modulation of voice by organs of articulation into basic building blocks, the 'phonemes'. Phonemes help in distinguishing one word from another in a particular language. Some sounds like clicks, whistling and whispering can be produced by organs of articulations without voice.

Because of anatomical, physiological, racial, cultural and social factors every human voice is unique and like fingetprints is the signature of each individual. It has vital role in both emotional and linguistic communication. For earning one's livelihood and to express feelings in one's occupation and personal interactions voice production skill is a must. Voice can give information about the speaker's age, sex, personality, emotional and health status.

A normal voice is coherent i.e., it is well planned, clear and sensible[2]. It results from the coordinated, intricate movements of the muscles larynx.

This is the most advanced sensorimotor system to be found in the human body. A harsh voice is a serious handicap to the speaker. Social contacts, professional and familial relationships suffer because of changes in voice. Voice disorders in lecturers, teachers, salesmen, actors or singers cause problems in profession.

As said earlier every voice is unique. Even in a given individual, voice can change according to his /her physical and emotional status. Hence defining a normal voice and measuring its parameters for an individual or a population is a difficult task.

It is logical to assume that the parameters of voice can be different for different disease entities. Before trying to correlate the parameters of voice with such entities it becomes obligatory to define what is normal.

The methods being used now by scoring of voice analysis by perception are fairly common. But they are subjective and won't yield to documentation.

The location of vocal folds makes it difficult to physically measure their movements. X-rays and ultrasounds are not of much use because cartilages surround the vocal folds. Video evaluation does not help since the movements of the vocal folds are quite rapid ( 80 to 300 Hz).[3,4] Stroboscopy and high speed videography need the instruments to be placed in the throat and cause gagging and laryngeal spasm and stop production of voice. Moreover all these procedures are invasive and cause discomfort to the patient.

Non-invasive physical measurements have a greater advantage in that they yield for an objective and documentable approach and can allow reliable comparison of voice samples (e.g., before and after treatment), therapeutic methods (e.g., microsurgery versus laser) etc[5].

In majority of ENT and Speech Therapy Units clinical evaluation of voice is still perceptive. But the modern era demands a reliable, documentable technique to quantify and standardise voice characteristics[6].

There are objective methods like computerised voice analysis which are non-invasive, fast and reliable and clinicians can easily setup a system for the purpose.

Though computerised analysis is being extensively used throughout the world no world standards have been established for normative parameters[7]. In a few attempts the data analysed is not large enough to proclaim universality of these parameters. It is needed to test on a larger database to make the parameters more universal.

In Indian context the research carried out is limited and the size of the data tested is quite small. The purpose of the current work is a) to create a large normal voice database of local population b) to evaluate this data and create standardised values of normative parameters.

*Reference :*

1. Mathieson L, Carding P. The Voice and speech production. In: Michael Gleeson.(Ed). Scott-Brown's Otorhinolaryngology and Head and Neck Surgery. 7th ed. London: Hodder Arnold, 2008; p. 2166-72.
2. Phoneme -Wikipedia. (n.d). Retrieved September 26, 2018. from https://en.wikipedia.org/wiki/Phoneme
3. Voice Analysis - Wikipedia. (n.d) Retreived Jan 30, 2017 from http://www.fact-index.com/v/vo/voice_analysis.html
4. Voice Analysis - Wikipedia. (n.d) Retreived Jan 29, 2017 from https://wikivisually.com/wiki/Voice_analysis
5. Toran KC, Lal BK. Objective voice analysis for vocal polyps following microlaryngeal phonosurgery. Kathmandu University Medical Journal. 2010; (8) 30 : 185-189.
6. Mehta DD, Hillman RE. Voice assessment: updates on perceptual, acoustic, aerodynamic, and endoscopic imaging methods. Current opinion in otolaryngology & head and neck surgery. 2008 Jun;16(3):211.
7. De Felippe AC, Grillo MH, Grechi TH. Standardization of acoustic measures for normal voice patterns. Brazilian Journal of Otorhinolaryngology. 2006 Sep 1;72(5):659-64.

## AIMS AND OBJECTIVES

1. To create a database of normal voices
2. To analyse and identify different parameters of these voices
3. To identify normative values of different parameters

## HYPOTHESIS

1. Even though voice is different from individual to individual and voice is unique for an individual human brain can identify normal voice and differentiate it from the abnormal.
2. Then the brain must be selecting some common parameters of all the voices to differentiate these from abnormal ones.
3. These parameters can be isolated from voices of normal indivduals and used to define parameters for normal voice,

**HISTORICAL ASPECTS**

Since ages the people have been dreaming of holding sounds and listening to it when they wanted.

Wolfgang von Kempelen invented Speaking Machine in 1769[1]. It took him 20 years of his life to work on it. It represented the model of the human vocal tract.

Kempelen used kitchen bellows to replace lungs,[2] A bagpipe's reed replaced vocal cords. He could produce simple vowel sounds. Later he improvised his machine to produce vowels, plosives, nasals and some words. Kempelen finally created a machine to produce 's' 'sh', and 'r' sounds. For the purpose he used several layers of tubes, rods and smaller bellows and a string operated flap to function as throat, nasal cavity, mouth and tongue[2].

After 40 years, Kempelen's work was well recognised by Charles Wheat stone[3]. But no development occurred till 19th Century.

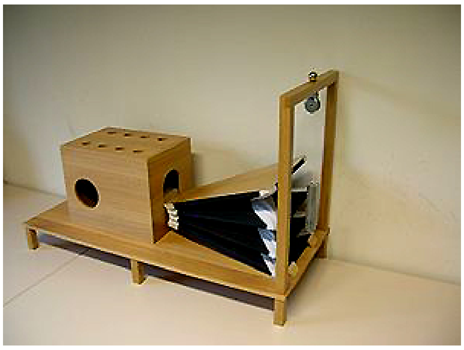


Fig 1- Speaking Machine replica built by Department of Phonetics, Saarland University, Saarbrucken, Gremany (Picture in Public Domain)

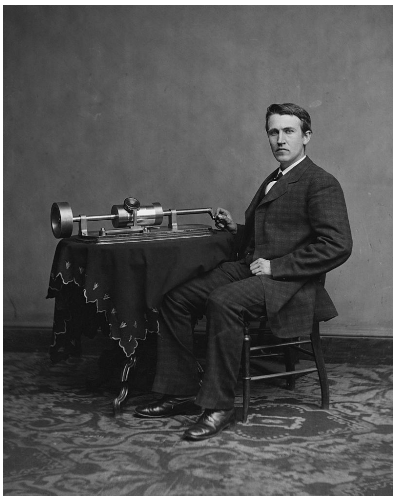


Fig 2 - Thomas Alva Edison, in 19th century invented the phonograph that could record and reprodue sound[4] (Picture in Public Domain)

Homer Dudley, a Bell Lab engineer, in 1928 developed the 'vocoder' that could code and decode speech signals[5,6]. This was splitting the voice signal into a number of frequency bands. The same were resynthesised to create original sound.

Homer Dudley, in 1937-38 again invented what he called 'voder'. This was an attempt to synthesize human speech electronically[7]. The speech thus produced had a lot of limitations in range as well as quality. Moreover it was a complex machine and required skill and experience to use it. Still it was a big leap in speech synthesis[8] .

Voiceprinting, a method of identifying a known voice, by aural as well as spectrographic comparision with unknown voices[9] . This was developed by Bell Laboratories in 1940 and was used in forensic laboratories.

In the beginning of 20th century people started to use Phonetics systematically. In Paris the first laboratory for experimental phonetics was established. Tuning forks and simple pneumatic apparatus were used. Speech sounds mainly vowels and their frequency characteristics were studied. Eventually speech labs started being established in different parts of the world[10].

*Reference :*


1. Kempelen W.V., “Le mechanisme de la parole, Suivi de la description d’une machine parlante”, J.V.Degen, 1791.
2. Wolfgang von Kempelen's speaking machine Wikipedia – (n.d.) -Retreived from Dec 24 2018, https://en.wikipedia.org/wiki/Wolfgang_von_Kempelen%27s_speaking_machine
3. Wheatstone C., “The scientific papers of Sir Charles Wheatstone Taylor and Francis”, London, 1879.
4. Phonograph – Wikipedia. (n.d.) -Retreived Dec 24, 2018, from https://en.wikipedia.org/wiki/Phonograph#Early_history
5. Vocoder Wikipedia- (n.d.) -Retreived from Dec 25, 2018, from https://en.wikipedia.org/wiki/Vo2. coder
6. Volta Laboratory and Bureau Wikipedia- (n.d.) -Retreived Dec 25, 2018, from https://en.wikipedia.org/wiki/Volta_Laboratory_and_Bureau
7. Voder Wikipedia- (n.d.) -Retreived Dec 24, 2018, from https://en.wikipedia.org/wiki/Voder.
8. Dixit VM, Sharma Y. Voice Parameter Analysis for the disease detection. Journal of Electronics and Communication Engineering. 2014 Jan;9(3):48-55.
9. Steve Cain, Lonnie Smrkovski, Mindy Wilson. Voiceprint Identification. Expert Pages, [accessed on Dec 24 2018] Available from https://expertpages.com/news/voiceprint_identification.htm
10. Laboratories of experimental phonetics. Experimental methods in Phonetics -(n.d.)Retreived Dec, 7 2017 from http://lib.chdu.edu.ua/pdf/pidruchnuku/18/83.pdf

**ANATOMY**

The tracheobronchial diverticulum appears at the 4th week of development from the anterior wall of the primitive pharynx. A partition called esophageal septum develops which fuses at the caudal level leaving an opening at the upper end at the pharynx. This results in a tube forming respiratory tract. Larynx and trachea are developed by its upper end. The lower end of the primitive pharynx develops into bronchi and lungs[1]. The cartilage, muscle and blood vessels of bronchi and lungs develop from the mesenchyma of the endoderm of foregut. By the side of this tube arytenoids and the aryepiglottic folds develop. Hypoglossal eminence gives rise to epiglottis. Fig.1 shows the development of Larynx.

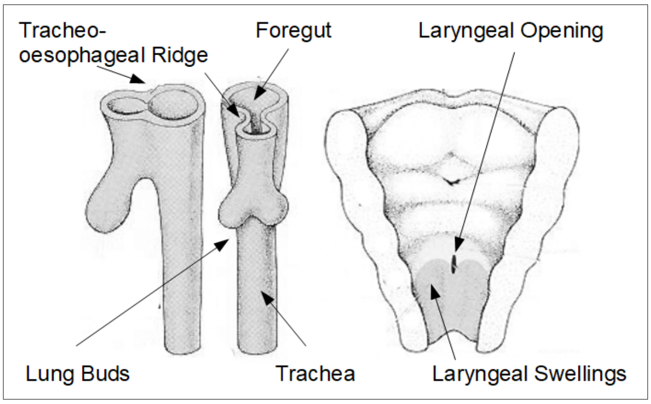



*Fig.3-Development of Larynx*

Larynx is a membrano-cartilaginous tube lying opposite to the cervical 3rd to 6th vertebra. It is funnel shaped in infants but softer and more compressible than adult. The size of larynx is more or less same in children in both sexes but changes after puberty. The anterio-posterior length at glottis level is 23-24 mm in females and 35-36 mm in males. The width of the larynx at the same level is 36-37 mm in females and 40-44 mm in males[2]. The dimensions are dipicted in Fig.2

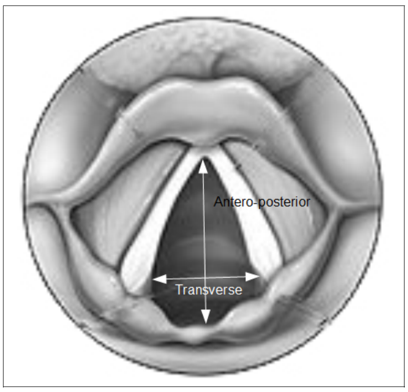



*Fig.4 - Diameters of the Larynx*

The larynx is divided into glottis, supraglottis and subglottis. The glottis includes vocal cords and their superior and inferior surfaces, anterior and posterior commissures. The part of the larynx above the glottis is called as supraglottis and contains epiglottis, aryepiglottic folds and false vocal cords. The area below the glottis upto the first tracheal rings is subglottis.

**Cartilages and bones of the Larynx**

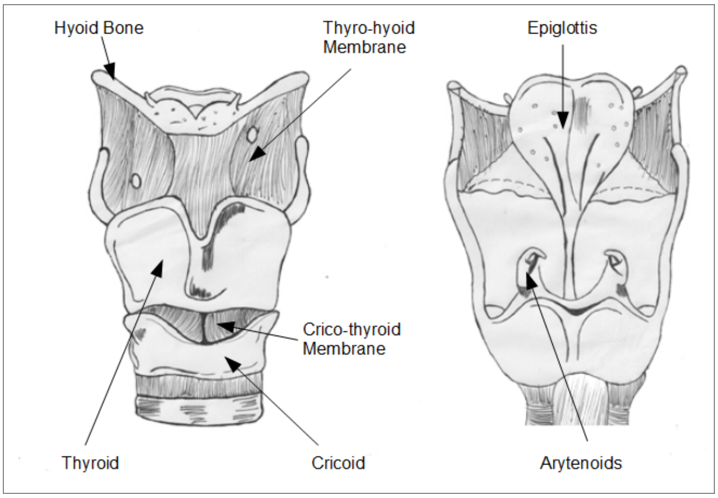



*Fig. 5 - Cartilages & Bone of Larynx*

*Thyroid cartilage* : The thyroid has two lamina fusing anteriorly at the midline. It makes an angle of 120 degree in females and 90 degree in males. The inner aspect of Thyroid has attachment of thyroepiglottic ligament from base of epiglottis. Below this both ventricular folds and true vocal folds attach on either side of the midline. Here, there is attachment of thyroarytenoid and vocalis muscle to result in anterior commissure.

*Epiglottis* : It is a leaf like fibro-cartilaginous structure that is attached to the inner lining of the thyroid cartilage at almost mid level. The aryepiglottic folds arise from the sides of the epiglottis and end at the arytenoid swellings.

*Arytenoid cartilages*: They are wedge shaped cartilages which are attached to vocal folds anteriorly through vocal process. Laterally its muscular process gives attachment to posterior and lateral cricothyroid muscle. Anterolateral surface has two attachments, upper part to vestibular ligament and lower part to vocal ligament.

*Cricoid cartilage* : It is the only complete circumscribed cartilaginous ring that encircles and makes subglottic part of the larynx. It has lamina posteriorly and arch anteroirly. It continues as trachea caudally and attaches to cricothyroid ligament superiorly. Arytenoid cartilages are attached to the upper surfaces posteriorly.

*Corniculate and cuneiform cartilages* : These are small cartilages attached to upper surface of the arytenoids.

*Hyoid bone* : It is a thin ribbon like bone which is above the thyroid cartilage. It is ‘U’ shaped and has a body, greater cornu and lesser cornu. Thyro-hyoid membrane attaches this bone to the thyroid cartilage.

**The muscles of the larynx** [1]

***A. Extrinsic muscles of larynx***:These muscles have attachments to the outside structures.

*Suprahyoid muscles* :They arise from skullbase and attach to hyoid. They are Mylohyoid, digastric, stylohypod and geniohyoid muscles. (Elevators of larynx)

*Infrahyoid muscles* : They arise from sternum and larynx and attach to hyoid. These are Sternohyoid, thyrohyoid, omohyoid and sternothyroid are the muscles.

**B. Intrinsic muscles of larynx**: They arise within the larynx and attach to different structures larynx.

*Abductors of Larynx* : Posterior cricoarytenoid muscle is the only abductor of larynx.

*Adductors of Larynx* : These are Lateral cricoarytenoid muscle, Transverse arytenoids, Thyroarytenoid muscle and Cricothyroid. Vocalis muscle changes the thickness of the vocalfolds. The muscles of larynx are depicted in Fig.4

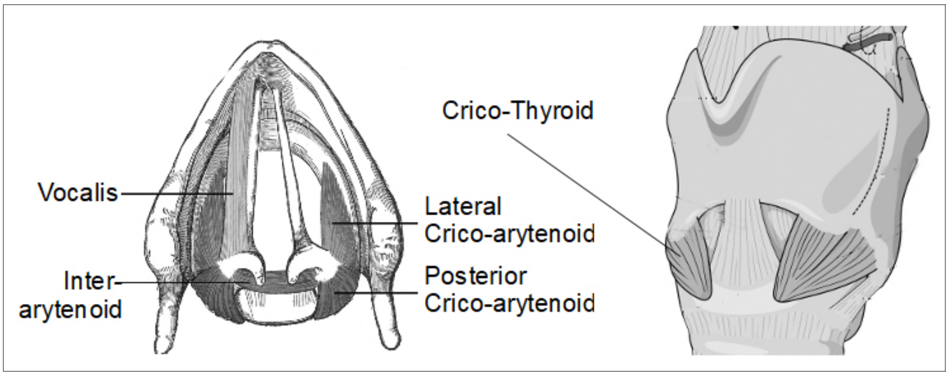



*Fig.6-Muscles of Larynx*

**Structure of Vocal folds**[2]

Vocal folds arise from vocal process of arytenoids and run up to the posterior surface of the thyroid lamina. It has 5 layers.

1. Epithelium-superficially squamous epithelium (non keratinising) is present
2. Lamina propia-Gelatinous subepithelial layer(Reinke’s space)
3. Intermediate layer-Elastic and collaginous layer forming vocal ligament and vocalis muscle lying lateral and deep.
4. Deep layer of lamina propia- macula flavae are cushion like structures which helps in

protecting the ends of cords during vibration.

5. Vocalis muscle-It is a part of thyroarytenoid.

The following figure shows the structure of Vocal Folds.

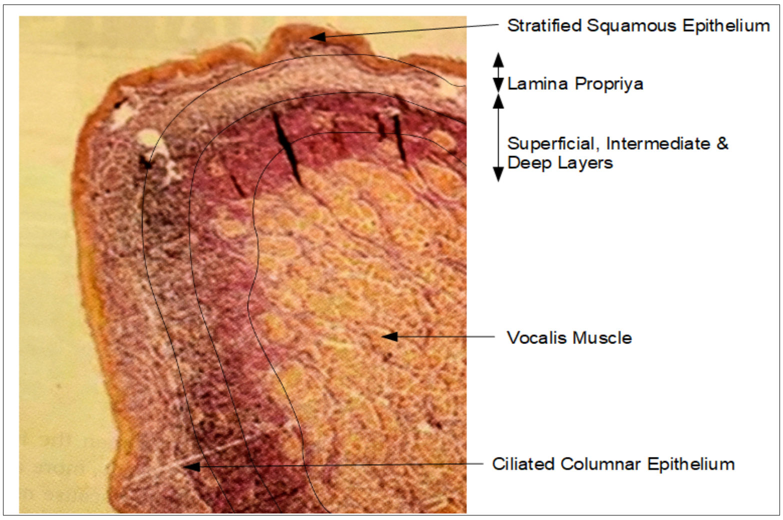



*Fig.7- Structure of Vocal Fold*

**Nerve Supply to the Larynx**

The superior and recurrent laryngeal branches of the vagus nerve provide both sensory and motor supply[3]. The superior laryngeal nerve arises from the inferior ganglion of vagus and supplies motor fibres to crico-thyroid muscle and sensory to the mucosa of the supraglottis through its external and internal branches respectively. The recurrent or inferior laryngeal nerve arise a little lower down , enters the thorax to hook around subclavian artery and aorta to return to the larynx. Rest of the muscles and the mucosa get their nerve supply through the recurrent laryngeal nerve.

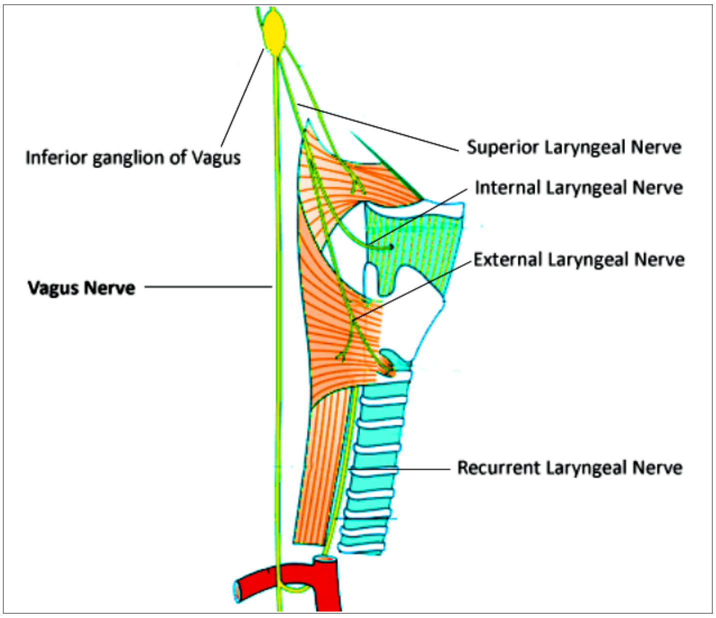



*Fig.8 -Nerve Supply to the Larynx*

**Respiration and Phonation**

Phonation is due to the vibrations of the vocal folds caused by forced passage of air through the glottis[4]. As such the larynx functions as a reed instrument. The lungs during expiration act as bellows and push air through the glottis. The vocal folds are the reeds. The larynx continues down into trachea which bifurcates into left and right principal bronchi. Each principal bronchus further divides into secondary and tertiary segments and bronchioles. Bronchioles terminate as small air sacs, the alveoli. The diaphragm lies at the base of thorax and is the main muscle of inspiration. As this muscle contracts and descends, air is sucked into the lungs through respiratory passage. Muscle of the rib cage wall, the external and internal intercostal, sternomastoid, pectoralis major and minor, scalene group, serratus group, latissmus dorsi and the muscle of the abdominal wall, the external and internal oblique, rectus abdominus and transversus abdominus do take part in expiration and phonation especially during production of loud sounds and in singing.

*References :*

1. Nigel Beasly. Anatomy of larynx and tracheobronchial tree. In: Michael Gleeson.(Ed). Scott-Brown's Otorhinolaryngology and Head and Neck Surgery 7th ed. London; Hodder Arnold; 2008.p 2130-45.
2. Gerhard. F, Georg PH, Gross anatomy of Larynx. In: Benninger.MS.(Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1st ed. New Delhi, The Health Sciences Publisher, 2016; p 23-43
3. Friedrich G, Lightenegger R. Surgical anatomy of the Larynx. J Voice. 1997;11(3):345-55
4. Boone DR, McFarlane SC, Berg SLV, Zraik RI. The voice and Voice Therapy. 8th edition, Boston: Allyn and Bacon; 2010.

## PHYSIOLOGY

Though phylogenetically larynx came into existance to protect the lower respitory tract, in humans voice production has become a vital function. The production of voice is effected by the controlled movements of the vocal folds and their tension. The vocal folds can be adducted and abducted through the actions of the intrisic muscles of the larynx. Laryngeal mechanoreceptors present in the mucosa of the larynx are sensitive to the airflow and the muscle stretch. The afferent information sent by them help in protection of the airway as well as in modulation of voice[1].

**Mechanism of Movements of Vocal fold**

The arytenoid cartilages rotate in an almost vertical axis. The posterior coricoarytenoid muscle rotates the cartilage internally thereby bringing the vocal process laterally along with the attached vocal process thus effecting abduction and widening of the glottis. The lateral cricoarytenoid and interarytenoid muscles rotate the arytenoid cartilage in externally and cause adduction. The cricothyroid muscle increases the distance between the arytenoid and thyroid cartilages thereby lengthening the vocal fold and increasing the tension. In this process it effects some adduction also. The vocalis muscle changes the thickness of the vocal fold. Extrinsic Muscles like sternohyoid, thyrohyoid, and omohyoid muscles, exert downward traction on the larynx. This action causes abduction of the vocal folds. The geniohyoid, anterior belly of the digastric, mylohyoid, and stylohyoid muscles exert upward force causing adduction[2].

**The mechanism of Phonation**

Voice production is said to be due to complex interaction between cerebral cortex, periaqueductal matter of midbrain and other subcortical loci[3]. According Davis et Al, the major categories of voiced and voiceless sound sounds are represented in periaqueductal matter of midbrain. Integration of cortical and subcortical aspects of language with basic respiratory and laryngeal motor pattern are integrated by this area of the brain. Phonemic differences, intonation and emotional aspects of the speech are controlled by the subcortical neural system. nucleus retro ambigualis controls vocalization, generation of respiratory pressure and coughing.

**The Neural Pathways**

The pathway for phonation starts in the motor cortex specifically in the precentral gyrus on both sides. The upper motor nerve fibres synapse with lower motor neurons by descending down to medulla. Some fibres decussate to the opposite side. Some of the neurons of the pyramidal tract have multiple offshoots and synapses with the basal ganglia and reticular formation[4]. Glossopharyngeal and vagus nerves get some connections from the frontal portions of pyramidal system and help in controlling articulation, phonation and respiration. Extrinsic and intrinsic muscles of larynx can be controlled voluntarily. Before phonation there will be pre-phonatory tuning. This is followed by the phasic, tonic and volitional contractions and also maintainance of length, tension, bulk and position of the vocal folds. The abdominal and intercostal muscle contractions are also regulated to maintain optimum subglottic air pressure.

**Biomechanics of Phonation**

Henry J Rubin (1960)[5] refers to the neurochronaxic hypothesis of Husson(1950). Husson presented the neurochronaxic hypothesis. According to this theory vocal fold vibrate rhythmically by receiving synchronous impulses through the nerves so that each vibratoion was caused by a separate neural impulse. He refutes neurochronaxic theory since it is physiologically not possible.

Johannes Muller in 1839 introduced myoelastic-aerodynamic theory of phonation. The vocal folds which are essentially passive are set into vibration by the rapid escape of air. The myoelastic refer to the tension and elasticity of the vocal folds. The dynamics of the passing air is the aerodynamic component. In 1958, Van Den Berg JW, modified this theory by adding that for the vocal folds to be sufficiently approximated the explanation can be given by Bernoulli Principle[6]. Subglottic pressure drives the vocal folds apart provided they are adequately adducted allowing the air to escape through glottis. According to him adequate adduction is necessory for the subglottic pressure to build up and drive the vocal folds[2].

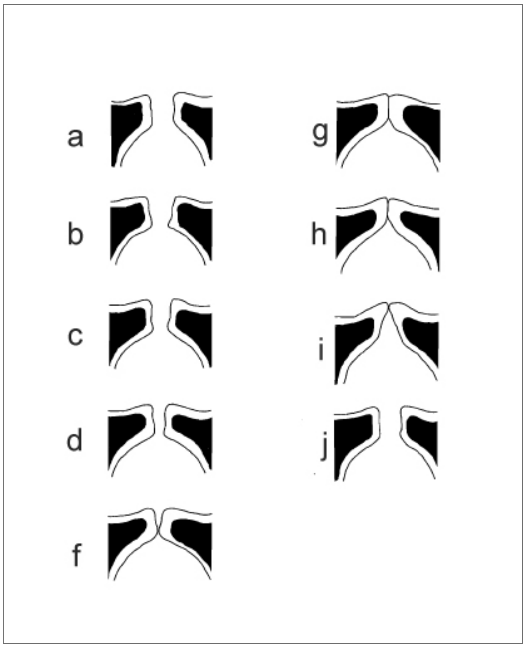



*Fig 9 - Vibratory Pattern of Mucosa*

Normal phonation requires that five conditions be satisfied.

1. The power of voice is generated by the building of pressure by breathing. This should create

a small gap in the glottis at the vibrating edges of the vocal folds.

2. The vocal folds should be anatomically and functionally favavourable for voice production.
3. The air is inhaled to fill the lungs, the glottis is closed, the vocal folds take a midline position.
4. On exhalation subglottic pressure builds up and the vocal folds are driven laterally. This results in sudden decrease in subglottic pressure. Elastic recoil forces in the vocal fold and the Bernoulli effect of airflow contributes to the return of the vocal folds to the midline. the Cycle is repeated when the vocal folds come to the midline and pressure in the trachea builds again.
5. A sufficient subglottal pressure of 3-5 cm of H2O is required to build up to blow the vocal cords apart.

This concept of phonation describes vocal fold to have three layers[7].

1. Body = Vocalis muscle and fibrous band
2. Transition Zone = superficial lamina propia
3. Cover = epithelium

The body of the vocal fold remains relatively static. The wave propagates in the mucosa, the cover. This wave begins on the inferomedial aspect of the vocal fold and moves caudally. The lower edges close as the superior edges of the vocal fold begin to separate. As the superior edges of the vocal folds separate, airflow through the divergent glottis generates greater negative pressure at the lower edge of the vocal folds, accelerating closure of the inferior glottis.

**Vocal Registers**

Vocal folds are capable of producing several different vibratory patterns that cause vocal registers. Clifton Ware[8] defines vocal registers as "A series of distinct, consecutive, homogeneous vocal tones that can be maintained in pitch and loudness throughout a certain range." A particular vibratory pattern of the vocal folds create a range of tones called vocal registers[9]. Modal voice(or normal voice), vocal fry, falsetto and the whistle are different kinds register[1]. Of these, whistle has the highest pitch and the vocal fry the lowest.

*Falsetto*

Vocal fold that are lengthened, thinned and tensed produce falsetto voice. The frequency band is 300-600Hz.

*Modal*

The vocal cord vibrate along the whole length of the free edge like figure of eight.The frequency is as in conversation and singing i.e. at the range of 100-450 Hz[1]

*vocal fry*

This has lowest vocal frequencies of 30-90Hz. Each vibratory cycle has long closed phase.

**Loudness**

It is the perceptual correlate of intensity of the sound. The factors that determine loudness are 1. Medial compression of vocal cords 2. The amount of Subglottic pressure 3. The duration, speed and degree of vocal fold closure[1]

**Pitch of voice**

It is the perceptual correlate of the frequency or vocal fold vibration. The determinants of pitch are the following -Length of vocal folds -Mass of vocal folds per unit per length -Tension of vocal folds. The Cricothyroid and Thyrovocalis are the main tensors that alter the pitch[1].

**Voice quality**

The voice quality distinguishes one from other voices of similar loudness and pitch[10]. The exact biomechanical determinants of the voice quality is still not known. The harmonics produced by a particular individual are unique for that individual and determine the quality. The anatomy and the functional differences determine the harmonics.

**The role of respiratory tract**

The subglottic pressure is the main reason for the primary driving force of the voice. The inspiration is due to active muscle contraction of diaphragm and external intercostals. This results in thoracic cage enlargement. Afterwards the air is expired and thoracic cage is decreased in size due to passive collapse of lungs[11].

The *passive forces* of expiration tend to generate force during inhalation that works to restore the lung and rib cage system. After active inhalation, these passive forces of exhalation rebound to provide some of the expiratory force needed for speech[12]. There is nearly linear relationship between relaxation and lung volume in the range between 20% and 70% of the vital capacity. This curve represents the pressure generated by the passive factors of the respiratory system. The voice qaulity is the best when passive forces are used for speech production.

*Active forces* : Sometimes active exhalation is done by muscles of respiration to produce speech. Sometimes abdominal muscles are also used. Vocal abuse can happen if the person uses the vocal folds squeezed in closed position instead of muscles of active forces. The vocal quality of most dysphonic patients can be changed by instructing them to use mid range of air pressure and lung volume[12].

**Vocal resonance and its modification**

The signal produced by vocal cords is weak and reedy. It sounds like a bleat of baby lamb. The vocal tract resonates and modifies this signal to produce a good voice quality. Finally the basic fundamental frequency produced by the vocal cords and the harmonics added by the vocal tract determine the timbre or the quality of voice.

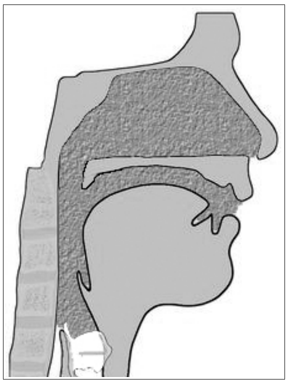


*Fig 10 - F - Configuration*

Since the anatomy of the vocal tract is unique for an individual and consequently the quality. The vocal tract, the resonator resembles the alphabet 'F' hence its structure is often refered as F Configuration[12].

*References :*

1. Gerhard. F, Georg PH. Biomechanics, Fundamentals of vibration, and Airflow. In: Benninger MS.(Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1st ed.vol.4. New Delhi: The Health Sciences Publisher. 2016; p. 51-62.
2. Jiang JJ, Hoffman MR. Biomechanics, Fundamentals of vibration, and Airflow. In: Benninger MS.(Ed). Sataloff's Comprehensive textbook of Otolqaryngology, Head and Neck surgery, 1st ed.vol.4. New Delhi: The Health Sciences Publisher. 2016; p. 51-62.
3. Davis PJ, Zhang SP, Winkworth A, Bandler R. Neural control of vocalisation:Respiratory and emotional influences. J. of Voice. 1996;10(1):23-38.
4. Mathieson L, Carding . The physiology of larynx. In: Michael Gleeson.(Ed). Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 7th ed. London; Hodder Arnold: 2008 p 2156-62.
5. Henry JR. Neurochronaxic theory of voice production/a refutation. Arch Otolaryngol. 1960;71(6):913-920
6. Van Den Berg J.W. Myoelastic-aerodynamic theory of voice production. J speech hear res. 1958;(1):227-43
7. Hirano. M. Clinical examination of voice. New York. Springer-Verlag;1981.
8. Ware C. Basics of Vocal Pedagogy: The Foundations and Process of Singing. New York: McGraw-Hill; 1998.
9. Vocal register – Wikipedia.-(n.d.)-Retreived from May, 28, 2018. https://en.wikipedia.org/wiki/Vocal_register
10. Mcglashan J, Fourcin A, Objective evaluation of Voice. In: Michael Gleeson.(Ed). Scott-Brown's Otorhinolaryngology and Head and Neck Surgery. 7th ed. London; Hodder Arnold; 2008.p155-65
11. Hixton, Hoit. J D. .Evaluation and management of speech breathing disorders: Principles and methods. Tucson AZ: Reddington Brown; 2005.
12. Boone DR, McFarlane SC, Berg SLV, Zraik RI. The voice and Voice Therapy. 8th edition, Boston: Allyn and Bacon; 2010.

**BACKGROUND OF VOICE EVALUATION**

From time immemorial, clinical assessment of voice disorders has been a real challenge to clinicians and voice pathologists. This is because the patients typically disagree for any type of their voice qualities. The measures of voice were studied from long back dating at least to Romans. Some of the scales of quality measures are not changed even after 2000 yrs. Austin(1806) refers to the proposals by Julius Pollux of 2nd century to describe voice like harsh, clear, bright, smooth, weak, shrill, deep, dull, thin, hoarse, and metallic[1].

Voice assessment by looking at severity, roughness, weakness and strain was proposed by Hirano(1981 GRBAS Scale).[2]

Due to a lot of controversies regarding reliability and validity of earlier proposals a new "*Consensus Auditory Perceptual Evaluation of Voice – CAPE V*" was proposed(Kreiman, J)[3]

Perceptual evaluation has several limitations like scale validity, reliability and definition of severity problems. These affect utility in the clinics and outcome measures, evidence based medicine and credibility in medico-legal cases[4].

The method of evaluation of quality of voice by a jury consisting of professionals though considered as most reliable in routine practice it is difficult to execute and reproduce[5].

In 1977, Hilman et Al felt that there was a need for an objective assessment that would give more insight into voice production and is more reliable[6].

Way back in 1963 Von Leden[7] used ultra slow motion pictures and observed vibratory patterns of vocal folds. Authors like Yumoto, Gould & Baer(1982) considered shimmer and harmonics-to-noise ratio in their studies[8].

Yumoto, in a study of 87 pathological voices found a significant correlation of harmonic noise ratio, jitter and spectrographic classification with psychological and physical degree of hoarseness[9].

Robert Hillman et al[6] demonstrated, to a high accuracy that acoustic measures can determine presence or absence of voice disorder.

Klinghotz et al[10] in his studies concluded that jitter perturbations are more efficient to discriminate functional disorders.

Because of profound advancements in information technologies many softwares were developed during 1990s.[11] MDVP[12], DR SPEECH[13], Vagmi[14], Computerized Speech Laboratory[15], PRAAT[16], and a hand marking voice analysis etc, are some of the systems developed for acoustic analysis.

They are useful in managing Speech Disorders, Communication, Disorders of

Language Delay, Hearing Impaired etc. They can also encompass digital stroboscopy systems, general endoscopy systems, swallowing and speech assessment, and therapeutic endoscopes. Some were deviced even for works like acoustic analysis tool used in the diverse fields of medicine, speech pathology, linguistics, bioacoustics, forensics, and military intelligence.

Many clinicians started using the same and analysed the voice samples for parameters like Jitter, shimmer, HNR, SNR, F0 etc, upto 30 parameters. Some were customised programs and adapted their own softwares and calculations. Hence the values of parameters measured were different from each other[17].

Haldun Oguzi et Al randomly selected 47 normal and abnormal voices and obtained jitter, shimmer and noise-to-harmonics ratio through two softwares - Praat[16] and MDVP[12]. Both gave similar results for fundamental frequency and shimmer. However jitter and noise-to-harmonics were significantly different[18].

Dibazar et al studied 700 subjects and tried automatic detection of abnormal voices[19]. They used non-invasive, fully automated measures that were non-expensive. The tool used was a Mel-frequency filter bank cepstral coefficients. These were designed using by "Gaussian mixtures in a hidden Markov model(HMM) model".

Orozco et al also tried automatic detection of abnormalities in voice production system. They estimated non-linear dynamic features using recordings of continuous text reading. Their results were successful to the tune of 95%. They opined that to detect abnormal voices non-linear dynamics studies are quite efficient[20].

The recent advances mentioned above are still under experimentation and are not available universally.

*References :*


1. Austin, G. (1806). Chironomia. London: Cadell and Davies. Reprinted by Southern Illinois University Press, Carbondale, IL; 1966.
2. Hirano M.Psycho-acoustic evaluation of voice: GRBAS Scale for evaluating the hoarse voice. Clinical examination of voice. London: Springer; 1981.
3. Kreiman J., Gerratt BR. Validity of rating scale measures of voice quality. Journal of the Acoustical Society of America, 104: 1598-1608.
4. Kreman J, Gerratt BR, Kempster GB et al. Perceptual Evaluation of Voice Quality; Review, Tutorial, and a framework for Future Research. J of Spee Hear res. 1993; 36(1): 21-40
5. Hartl DM, Hans S, Crevier Buchman L, Laccourreye O, Vaissiere J, Brasnu D. Dysphonia: current methods of evaluatio. Ann Otolaryngol Chir Cervicofac. 2005;122(4):163-72.
6. Hillman RE, Montgomery WW, Zeitels SM. Appropriate use of objective measures of vocal function in the fd multidisciplinary management of voice disorders. Cur Opinion in Otolaryngol & H and N Surg. 1997; 5: 172–75.
7. Moore GP, White FD, Von Leden H. Ultra high speed photography in laryngeal physiology. Journal of Speech and Hearing Disorders. 1962 May;27(2):165-71..
8. Yumoto E, Gould WJ, Baer T. Harmonic to Noise Ratio as an index of degree of hoarseness. J Acoustic Soc America. 1982 Jun; 71(6): 10544-50.
9. Yumoto E, Sasaki Y, Okamura H. Harmonics-to-noise ratio and psychophysical measurement of the degree of hoarseness.J Speech Hear Res. 1984 Mar;27(1):2-6.
10. Klingholz F, Martin F. Quantitative spectral evaluation of shimmer and jitter. J Speech Hear Res. 1985 Jun;28(2):169-74.
11. Boone DR, McFarlane.SC, Shelley L, Berg V, Zraick RI. The Voice and Voice Therapy. 8th Edition. Boston: Pearson ;2005.
12. Multi-Dimensional Voice Program 3.3. Software Informer. Retreived from May 8 2018. Available from https://multi-dimensional-voice-program.software.informer.com/
13. Tiger DRS Inc. Retreived from May 8 2018. Available from http://www.drspeech.com/
14. Voice and speech Systems. Retreived from May 2018. Available from https://www.vagmionline.com/
15. Romak JJ, Heur RJ, Hawkshaw MJ, Sataloff RT. The Clinical Voice Laboratory. In: Sataloff RT (Ed). Professional Voice - The Science and Art of Clinical Care. 4 th edition. San Diego, CA: Plural Publishing, 2017; p. 405-439.
16. Boersma P., Weenink D., “PRAAT: Doing phonetics by computer”, Version 4.3.14, Computer program, 2005.

17. Filleppe ACN, Maria HM, Martelletti G, Thaís HG. Standardisation of acoustic measures for normal voice patterns. Rev bras otolaryngol. 2006 ;72 (5): 659-664.
18. Haldun O, Mehmet Ak, Mustafa AŞ. Comparison of results in two acoustic analysis programs: Praat and MDVP. Turk J Med Sci. 2011; 41 (5): 835-841.
19. Dibazar and S.S.Narayanan. Feature analysis for Automatic detection of normal and pathological–MFCC. A paper presented at; Engineering in Medicine and Biology, 2002. Proceedings of second joint at 24th Annual Conference and the Annual Fall Meeting of the Biomedical Engineering Society EMBS/BMES Conference, Oct .2002. Houston, TX, USA, USA
20. Orozco JR, Vargas JF, Alonso JB, Ferrer MA, Travieso CM, Henríquez P. Voice pathology detection in continuous speech using nonlinear dynamics. In2012 11th International Conference on Information Science, Signal Processing and their Applications (ISSPA) 2012 Jul 2 (pp. 1030-1033). IEEE.

## VOICE ANALYSIS, ASSESSMENT AND EVALUATION

Since voice may be affected by physical, emotional, professional and social factors the Clinician, ENT surgeon or speech pathologist has to evaluate the patient in entirety. The enquiry should be exhaustive and should consider all these factors. Authors like Sataloff and Daniel R.Boone have refered to protocols of enquiry proposed by different authors[1,2].

In 2004 American Speech-Language-Hearing Association (ASHA) gave a comprehensive protocol for voice assessment, evaluation and treatment[3],.

1. Auditory and visual status assessment
2. Case history, particularly vocal usage, occupation, medical status, vocation, cultural and linguistic background
3. Examination of the patient by standardised and non-standardised methods
    1. Perceptual analysis of vocal production
    2. Acoustic analysis of voice
    3. Physiological aspects of vocal behaviour
    4. Patient’s ability to modify behaviour
    5. Psychologjcal/Emotional status
    6. Medical history
    7. Review of articulation, fluency and language
    8. Functional consequences of voice disorder
4. Use of instruments and perception including
5. Videostroboscopy
    1. Electroglottography
    2. Aerodynamic measures
    3. Acoustic analysis
    4. Perceptual ratings

### Subjective Analysis

The trained clinician can assess one's voice by listening to it. He/she will consider different parameters like loudness, pitch and timbre. The method does not require any instrumentation and is fast, fairly accurate and comparable among different evaluators. However, since it is still subjective, objective documentation is not possible.

Different scales are proposed for the assessment. The following two are commonly used.

*GRBAS Scale*.[4]

GRBAS Scale was Developed by Committee for Phonatory Function of the Japanese Society of Logopedics and Phoniatrics. It is one of the commonly used scales. The parameters considered are

1. Grades of Severity
2. Roughness
3. Breathiness
4. Asthenia
5. Strain

The gradings are 0,1,2,3 and 4 for normal, mild, moderate and severe abnormality respectively.

*CAPE V (Consensus auditory perceptual evaluation of voice )*[5]

Speech pathologists are increasingly using this scale. This was introduced by International Conference sponsored by Special Interest Division of Voice and Voice Disorders of the American Speech-Language-HearingAssociation in June 2002. It is visual analogue scale of 100mm line. The test material is six standard sentences, two sustained vowels, and 20 seconds of natural speech. The parameters evaluated are roughness, strain, pitch, severity, breathiness and loudness. A more severe deviation from normal quality is indicated by higher scores[6].

**Material for evaluation**

A vowel sustained for some time, a phrase, a running or spontaneous speech or a passage read are used for perceptual evaluation[7]. In a given scale, extreme ends of the spectrum (normal and severe) are rated more reliably than the intermediate points.

*The sustained vowels*

In clinical practice sustained vowels are commonly used. /a/, /e/, /u/ at comfortable loudness and pitch are generally used as they are simple and easy to measure.

In a recorded file of sustained vowel, the onset and end portions are unstable. The midportion of the file is thought to be more stable and represent the intrinsic quality of a voice.

*Connected speech*

Connected speech (running or spontaneous speech or a passage read) is nearer to day to day normal conversation.

*Consonant-vowel sequences for speech*

Rapid voice alterations like alternate voiceless consonants with a vowel, e.g. 'pu-tu-ku' or 'pu-terr-kerr' test the diadochokinetic sound sequencing capabilities. Sound sequence as pu-pu-pu….. pronounced rapidly provide an assessment of the resistance of the laryngeal airway[8].

**Objective Analysis**

*Visualisation of larynx and vocal tract*

1. Indirect laryngoscopy
2. Flexible laryngoscopy
3. Rigid videolaryngoscopy
4. Videostroboscopy

*Indirect Laryngoscopy*

Involves examination of the larynx using an indirect laryngral mirror.[9] This procedure has been adopted by ENT surgeons for ages. It has the convenience of a less expensive, simple opd procedure without the use of an elaborate equipment. However, the visualisation is not perfect with some hidden areas of larynx not seen, illumination is not very good and there is no magnification. It may not be possible to perform in children and in some individuals producing gag reflex.

*Angled telescopic assessment of Larynx*


*Fig 11 - Set up for Telescopic Examination of Larynx*

The rigid Hopkins Telescopes of 70 or 90° angled lenses can be used to view the larynx. They have higher optical resolution and good illumination that help in detailed assessment of larynx.[10] After anaesthetising the pharynx with a local anaesthetic the tongue is pulled forward by holding with a gauge piece and the telescope, connected to a camera and monitor is introduced just behind the soft palate. Structures all the way from the base of the tongue to the tracheal rings are examined methodically. The movements of the vocal cords are noted. The procedure has the advantage of excellent illunation, good magnification and possibility of recording.

*Flexible laryngoscopy*[2]

Under surface anaesthesia the scope is passed through the nose along the floor and negotiated all the way to the introitus of the larynx. The vallecula, epiglottis, aryepiglottic folds. False and true vocal cords, commissures, subglottis and the tracheal rings are visualised systematically.[11]

*Rigid laryngoscopy[10]*

Under general anaesthesia the rigid laryngoscope is passed through pharynx to visualise larynx. Anterior commissure scope is useful for viewing anterior commissure and anterior part of glottis. Suspension laryngoscope makes both hands free to operate for microlayngeal surgery by using the microscope.[2]

*Contact endoscopy and microlaryngoscopy*

This is more of a research tool wherein Methylene blue or Lugol's iodine is applied to surface of larynx. Using a microscope with magnifications of 150x and 60x the cell morphology like nuclei and cytoplasm can be studied. Premalignant changes can be easily noted early.[12]

*Electroglottography (EGG)*

It is a graphical tracing representing the electrical current conducted through laryngeal tissues.[13] Being a good conductor of electricity, the laryngeal tissues can conduct the current when both vocal cords come together. On the anterior part of neck, at the level of thyroid lamina, two electrodes with a high-frequency, low-current signal are placed and measure the conductance or impedance between them.

*Videostroboscopy*

*Fig 12 - Videostroboscopy*

Videostroboscopy is the most practical and useful technique for clinical evaluation of the movements of the vocal cords.[14] Cycle to cycle variations of vocal cords with vibration and visco-elastic properties of mucosa can be studied with this advanced imaging technique.[15].

*Physical principle and concept of stroboscopy*[16]

A pulsatile light thrown through an endoscope creates an illusion of slow motion of the vocal cords. The rate of pulsations can be adjusted so as to make the vocal folds appear in slow motion or stationary. This way the cycles of vocal fold vibrations can be visualised in isolation. The equipment also has the provision to automate the flashing rate in synchrony with the rate of vocal fold vibrations. This way we can assess phase symmetry, regularity, glottal closure, amplitude, mucosal wave, vibratory behavior, level of the vocal folds, phase closure, supraglottic activity and free edges of the vocal folds. The observations can be recorded.

*Laryngeal ultrasonography or Ultrasound glottography-(UGG)*

A less commonly used tool that can give some information about the structure of the larynx and movements of the vocal cords[17].

**Newer laryngeal imaging technologies**

Newer laryngeal imaging techniques like high speed videoendoscopy, magnetic resonance imaging, and optical coherence tomography have been proposed but have not established as regular tools[18].

MDVP[19], DR SPEECH[20], Vagmi[21], Computerized Speech Laboratory[22], Frequency Analyser[23] and PRAAT[24] etc, are some of the systems developed for acoustic analysis.

Kay Elemetrics Corp. developed Multi-dimensional-voice-program and released their first version 3.18 in 2009[19]

*Dr.SPEECH* : Daniel Huang, the director of the Speech and Hearing Sciences Key laboratory at East China Normal University in Shanghai, China, has developed a complete platform for comprehensive management of speech. Dr. SPEECH claims to be useful in managing Speech Disorders, Communication, Disorders of Language Delay, Hearing Impaired, Learning Disabilities, Brain Injuries, , Cerebral Palsy and more[20].

Dr. T.V Ananthapadmanabha, through *Voice and Speech Systems* (founded in 1985) has developed VAGMI. VAGMI is said to be specially designed for Indian Languages. It is more of a tool for speech pathologists and therapists than for basic analysis[21].

Pentax Medical has a comprehensive equipment that encompasses digital stroboscopy systems, general endoscopy systems, swallowing and speech assessment and therapeutic endoscopes to include Computerized Speech Laboratory[22].

Frequency Analyzer System invented by Harry R. Foster, East Orange, and Elmo E. Crump at Ohmega Laboratories is a sound spectrograph device. The Sona-Graph is the commercial form of Frequency Analyzer System manufactured by KayPENTAX, a benchmark acoustic analysis tool used in the diverse fields of medicine, speech pathology, linguistics, bioacoustics, forensics, and military intelligence[23].

Praat is one of the most common tools used in voice analysis. It has also got support for speech synthesis and articulatory synthesis. It is a free software package designed, by Paul Boersma and David Weenink of the University of Amsterdam.[24]

**Voice Analysing Techniques**

Speech contains the basic sound produced by the vocal folds along with the resonance caused by the vocal tract and the modification added by the organs of articulation like lips, tongue, palate etc. Linear predictive coding is a mathematical model and an electronic procedure wherein the overall sound of speech is filtered to leave behind only the sound produced by vocal folds-residue.[25]

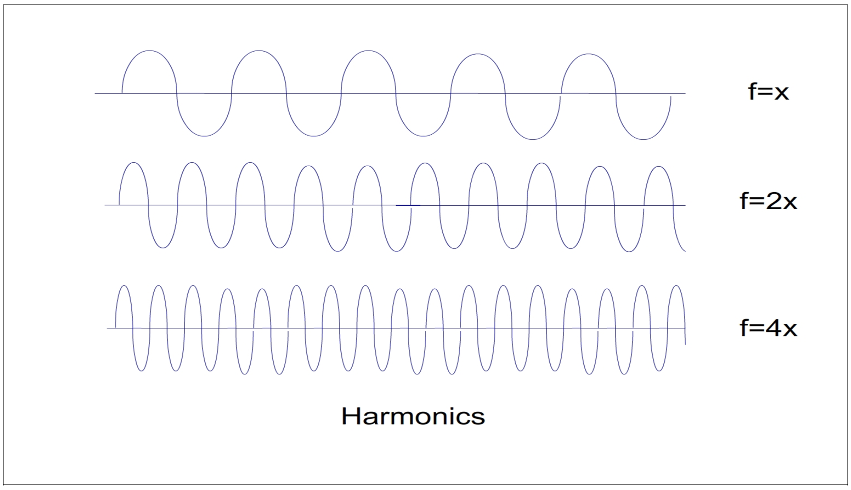



*Fig 13 - Harmonics*

A natural sound, unlike the sound produced by a tuning fork or an audiometer is not a pure tone with only one frequency. It always contains overtones or *harmonics* and some noise. Harmonics are the integral multiples of the fundamental frequency. The *Discrete Fourier transform (DFT)* decomposes such a sound into its constituent frequencies. This is done by complex mathetical algorithms and electronic equipment.

*The fast Fourier Transform(FFT)* is a mathematical tool for computation. It is a fast and efficient method of computing the discrete Fourier Transform of a series of data samples[26].

The *Long-term Average Spectrum* is a method of assessing quality by averaging the frequencies to draw formants[27]. A long sound sample of duration say 20-40 seconds contains a collection of all the components of sounds. The resulting spectrum is not influenced by the specifics of speech like accent, articulation, pattern etc. The first Formant, F1 and second Formant, F2 are affected by changing vowels. F3, F4 and F5 remain uniform over the length of sound. These decide the quality of voice.

**Acoustic Measures**

Depending on the information required out of a sound signal there are a variety of ways of analysis.

We should remember at this juncture that human voice is a complex acoustic output dynamically varying over time, in frequency content, amplitude, harmonics and noise and also their proportion. In majority of voice analysis the given signal is broken down into a series of sine waves by Fourier Transform. In each of them all the above parameters are captured on a time domain of spectrogram and their values are calculated[28].

The most of the analyses address the common parameters :

1. Frequency or Pitch
2. Amplitude or Volume
3. Perturbation
4. Harmonics

***Frequency***

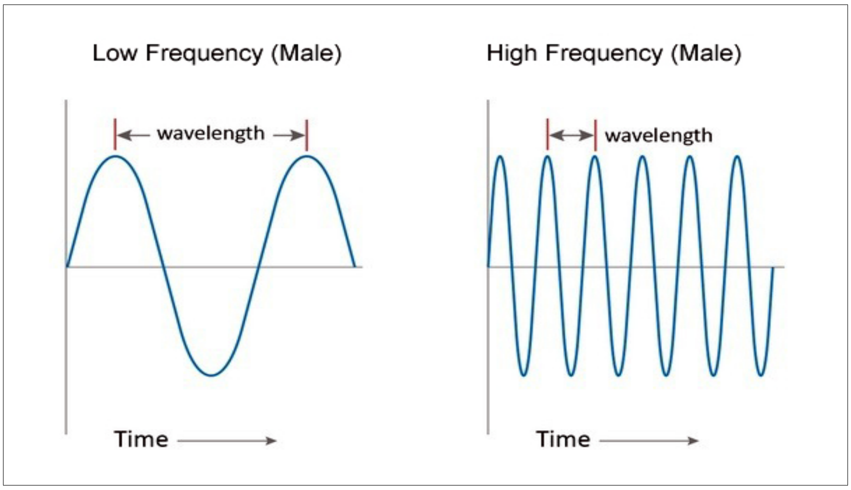



*Fig 14 - Frequency*

Frequency is the number of cycles per second in a sinusoidal wave form and is refered to as Hertz(Hz). In natural periodic sounds like musical notes and human voice there is no single sinudoidal wave. Rather it is a combination of a varieties of such waves produced at the same time. Of these one frequency, the lowest is of highest intensity and is percieved by the ear as that frequency. This is refered to as Fundamental Frequency(F0)[8].

In human voice the fundamental frequency is usually 85 to 180 Hz in men and 165 to 255 Hz in women[29].

The fundamental frequency is extracted at different contexts depending on the need of the investigator.

*Speaking fundamental frequency* is an average of the fundamentals delivered over a period of speech or while reading a passage.[30]. This is usually perceived as the pitch of that person's voice. However there is always some amount of Frequency Variability. With low variability the voice appears monotonous. In diseases like Parkinsonism variability as well as intensity are reduced. At the same time good speakers use Fundamental Freqency variations to their advantage by controlled modulation of their voice.

*Phonational Frequency Range* is the the total range, from lowest to the highest frequency that the human voice can cover[31]. Though majority of non-singers can cover just an octave, trained singer's voices can travel over 2 to 3 octaves. Anything beyond is rare and in majority of the times causes a lot of strain.

**Intensity (Amplitude)**

Sound is an energy and the power carried by this energy is refered to as Sound Intensity or Acoustic Intensity. It is measured as energy per unit area along the direction of wave propagation[32]. As in all wave motions the sound intensity diminishes inversely proportional to the square of the distance from the source of sound[33].

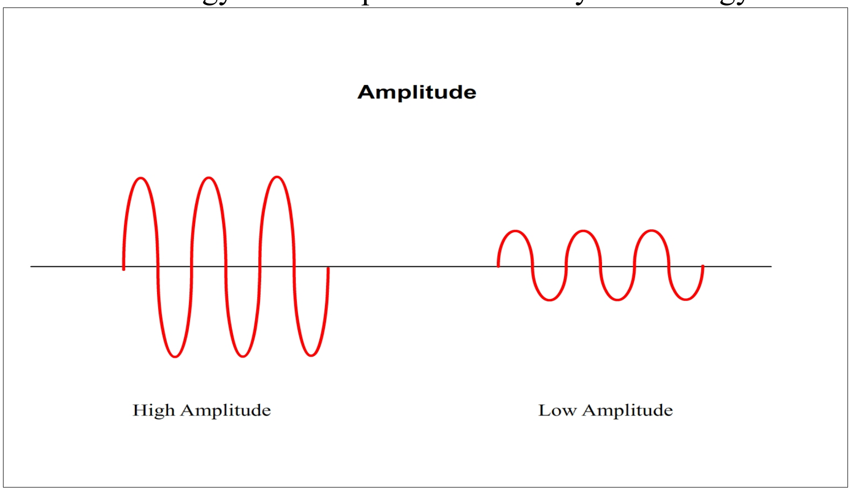



*Fig 15 - Intensity(Amplitude)*

Sound Intensity is measured as dB or Decibel. Human ear is so sensitive that it can appreciate sound energy levels from 10 to 1,00,00,00 of sound pressure level. Since this value is practically unwieldy for routine use, a logarithmic scale, dB is developed. Thus a sound 100 times powerful is 20 dB and 1000 times is 30 dB. On the decibel scale, the range of human hearing extends from 0 dB, wherein it is almost inaudible, to about 130 dB that can cause pain. The Absolute threshold of hearing in humans is defined as the minimum intensity of sound that can just be heard by normal young adults for 1000 Hz in a controlled environment and is refered to as 0 dB. It is generally reported as the RMS sound pressure of 20 micropascals. The sensitivity of the ear is different for different frequencies maximum being for 2 kHz to 4 kHz.

P***honetogram***

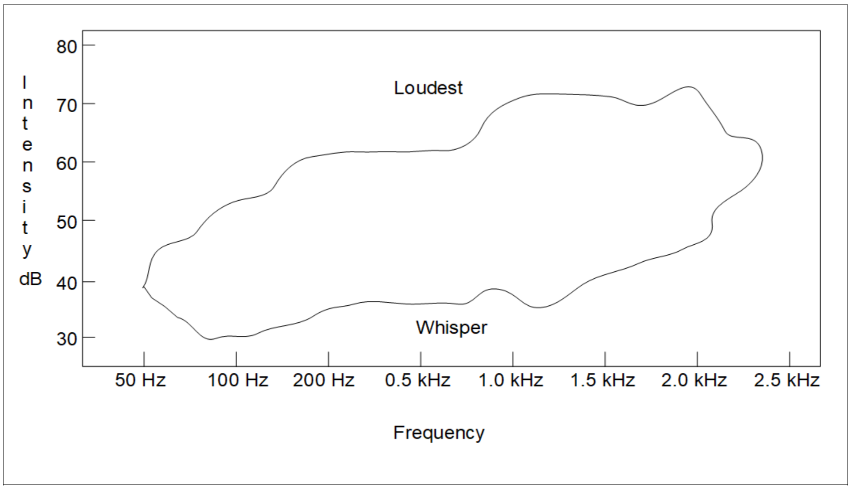



*Fig 16 - Phonetogram*

It displays the dynamic range of the human voice in terms of both fundamental frequency (pitch) and intensity (loudness). This display can be useful in identifying the limits of vocal function. In dysphonias the shape of the phonetogram changes[34].

**Spectrogram**

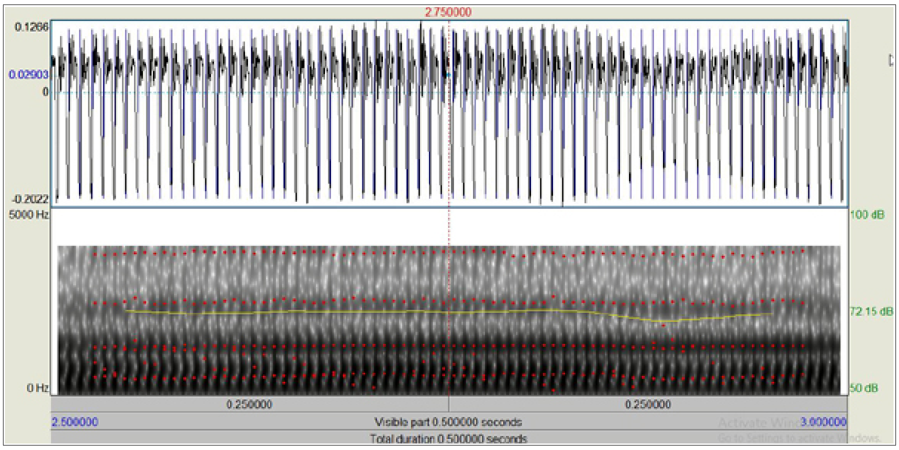



*Fig 17 - Spectrogram*

A spectrogram is a graphic presentation of a sound signal as it varies with time. The time is scaled on x-axis where as y-axis represents frequency. The intensity at any given time for a particular frequency is represented by changes in colour or the density of gray scale[35]. The spectrogram is generated by any of the following methods :

1. Fourier transform,
2. optical spectrometer or a
3. bank of band-pass filters.

We have used the spectrogram to resample the signal, extract formants and other voice parameters.

**Variation Measures**

**Jitter**

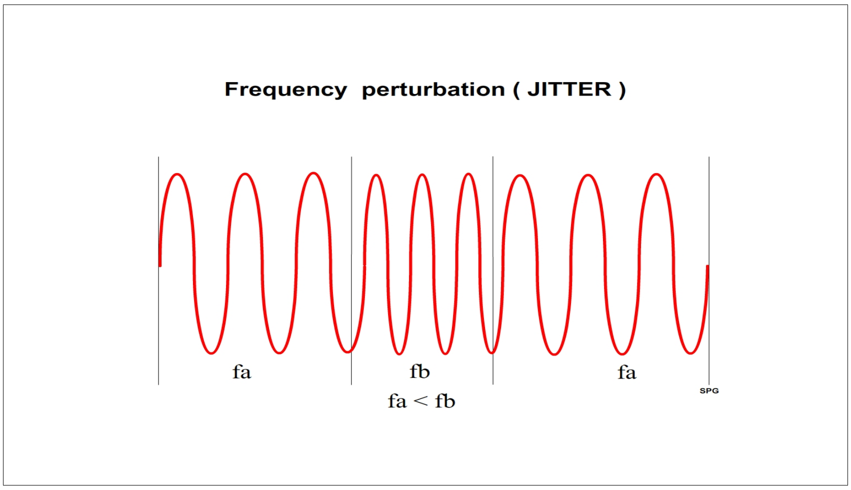



*Fig 18 - Jitter ( Frequency Perturbation)*

Perturbations are variations in acoustic signal. Since human voice is quasiperiodic and never perfect, perturbations in a long, normal voice are inherent[2]. Hence perturbations from cycle to cycle are more significant. Perturbations can be in frequency (jitter) or in amplitude(shimmer). Normally these are very minimal ( jitter <0.5%, Shimmer < 0.7dB) and not recognised during routine interactions[2].

**Shimmer**

Shimmer is the perturbation in the intensity or amplitude of a sound signal.

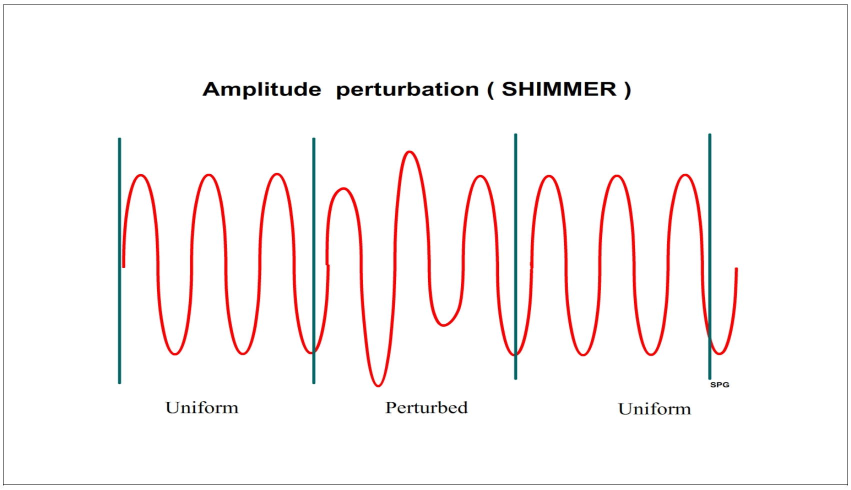



*Fig 19 - Shimmer(Amplitude Perturbation)*

**Harmonic to Noise Ratio**

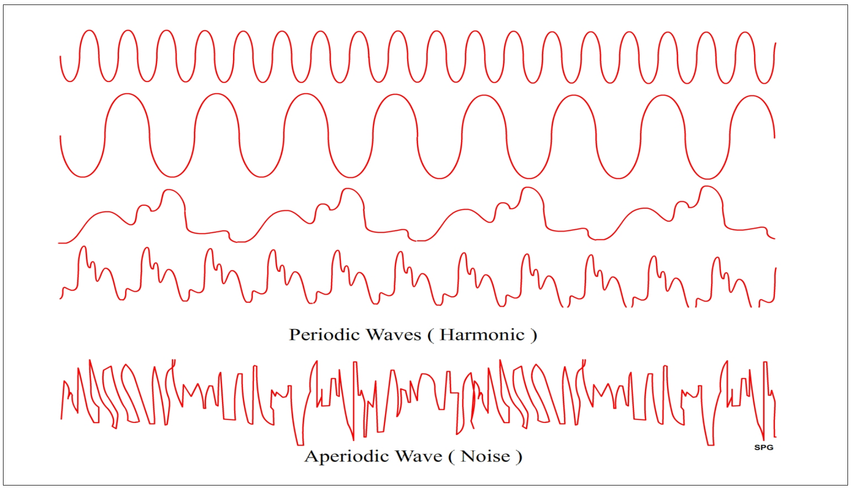



*Fig 20 - Harmonics & Noise*

During voice production the vocal folds vibrate almost, but not perfectly periodically[36]. Thus normal voice is a mixture of periodic signals and aperiodic ones. Aperiodic energy is refered as noise. Since lesser the noise better the voice a ratio of periodic to aperiodic energy is a good indicator of healthiness of voice and vice versa. Noise is produced by either turbulent airflow that impairs glottic closure or aperiodic vibration of the vocal folds[8].

*Drawbacks of perturbation measures :*

Perturbation analysis can be performed only for nearly periodic signals because accurate measurement of fundamental frequency is a must for such analysis. Severely dysphonic voices are often aperiodic hence may not yield reliable results[37].

**Other Acoustic Measures**

*Aerodynamic measurements*

The air flow through the glottis and subsequently through the whole vocal tract has a significant influence on the resultant voice. Hence aerodynamic measures are partinent[38]. They provide indirect evidence of functional bearing on the valvular effect of the larynx.

The common measures are

1. Lung volumes and capacities
2. Airflow
3. Air pressure

Reduced *Lung Volume* can not build up adequate subglottic air pressure and thus can not push the vocal folds apart. Diseases that reduce lung volume like COPD affect the quality of voice. Lung volume can be measured by a Spirometer.

*Air flow* is the volume of air displaced during phonation. It is standardised for a sustained vowel and is measured in cubic centimeters. Normally it is about 100cc/sec. Anything more results in breathy voice. A *Pneumatotachograph* is used for the purpose[39].

*The maximum phonation time (MPT)*

It is measured by asking the subject to inhale as deeply as possible and then sustain a steady [ a ] vowel for the longest possible time. It indicates glottal competence. Time less than 10.5sec is regarded as abnormal[1,2].

*s/z Ratio* is an indirect index of glottic airflow. Time to hold as long as possible on pronouncing 's' and 'z' is recorded. Normal individuals can hold for nearly the same time for both 's' and 'z'. In pathological voices the /z/value will be decreased but not on the /s/ time. In vocal fold palsy and other lesions Increased ratio is found[40].

*Air Pressure*

The cords start to vibrate when tissue resistance of the vocalfolds is less than the subglottic pressure. A minimum of 5-10 cm of water of subglottic pressure is needed to induce oscillation. This can be decreased in vocal fold palsy, neuro-muscular conditions and lung parenchymal diseases[41]. In hyperfunctional and spasmodic dysphonias the subglottic pressure is high. Measuring subglottic pressure is done by utilising a pressure transducer kept in vocal tract by a puncture in cricothyroid membrane or trachea, or negotiating to the subglottis through nose into the oesophagus[42].

*Quality-of-life measures*

It is quite challenging to assess the impact of voice disorder on the quality of life. The assessment has to cover general assessment and assessments related to communication handicap[43]. For such assessments questionnaires for the patient are developed. Some of the questionnaire are :

1. Patient questionnaire -vocal performance[44,45]
2. Voice-related quality of life
3. Voice handicap index[44]
4. Voice symptom scale
5. Voice activity and participation

The results can be inaccurate since the person fails to understand the impact of voice disorder on quality of life.

*References*

1. Patel RR, Harris SM, Halum SL. Objective voice Assessment. In: Benninger M. (Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1st Ed. New Delhi: The Health Sciences Publisher, 2016; p. 155-66.
2. Boone DR, McFarlane SC, Berg SLV, Zraik RI. The voice and Voice Therapy. 8th edition, Boston: Allyn and Bacon; 2010.
3. American Speech-Language-Hearing Association(2004 D).Preferred practice pattern for the profession of Speech Language Pathology. [Rockville MD : Author]. [cited on May 6 2018]. Available from www.asha.org/policy
4. Hirano M. Psycho-acoustic evaluation of voice. GRBAS Scale for evaluating the hoarse voice. In: Clinical examination of voice. Vienna: Springer;1981.
5. Nemr K, Simões-Zenari M, Cordeiro GF, Tsuji D, Ogawa AI, Ubrig MT, Menezes MH. GRBAS and Cape-V scales: high reliability and consensus when applied at different times. Journal of voice. 2012 Nov 1;26(6):812-17.
6. Zraick RI, Kempster GB, Connor NP, Thibeault S, Klaben BK, Bursac Z, Thrush CR, Glaze LE. Establishing validity of the consensus auditory-perceptual evaluation of voice (CAPE-V). American Journal of Speech-Language Pathology. 2011.
7. Mathieson L, Carding P. The Voice and speech production. In: Michael Gleeson.(Ed). Scott-Brown's Otorhinolaryngology, Head and Neck Surgery. 7th ed. London: Hodder Arnold, 2008; p. 2166-72.
8. Mcglaushan J, Fourcin A. Objective evaluation of the voice. In: Michael Gleeson. (Ed). Scott-Brown's Otorhinolaryngology and Head and Neck Surgery. 7th ed. London: Hodder Arnold, 2008; p. 2172-78.
9. Nigel Beasly. Anatomy of larynx and tracheobronchial tree. In: Michael Gleeson.(Ed). Scott-Brown's Otorhinolaryngology and Head and Neck Surgery 7th ed. London: Hodder Arnold, 2008; p. 2130-45.
10. Jeannon JP, Macnamara M. Assessment and examination of the upper respiratory tract. In:Michael Gleeson. (Ed). Scott-Brown' s Otorhinolaryngology and Head and Neck Surgery. 7Ed. London: Hodder Arnold, 2008; p2145-56.
11. Gerhard. F, Georg PH, Gross anatomy of Larynx. In: Benninger.MS.(Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1st edition. New Delhi, The Health Sciences, 2016; p.23-33.
12. Warnecke A, Averbeck T, Leinung M, Soudah B, Wenzel GI, Kreipe HH, Lenarz T, Stöver T. Contact endoscopy for the evaluation of the pharyngeal and laryngeal mucosa. The

Laryngoscope. 2010 Feb;120(2):253-8.

13. Hanson DG, Gerratt BR, Ward PH. Glottographic measurement of vocal dysfunction: a preliminary report. Annals of Otology, Rhinology & Laryngology. 1983 Sep;92(5):413-20.
14. Hirano M, Bless DM. Videostroboscopic examination of the larynx. 1st edn. London: Whurr Publishers Ltd; 1993.
15. Boehme G, Gross IVI. Stroboscopy and other techniques for the analysis of vocal fold vibration. 1st edn. London: Whurr Publishers; 2005.
16. Woo P. Stroboscopy and High speed video examination of Larynx.. In: Benninger.MS.(Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1st edition.New Delhi:The Health Sciences, 2016; p.23-33.
17. Nasr WF, Amer HS, Askar SM, Enaba MM. Laryngeal ultrasound as effective as CT scans for the diagnosis of various laryngeal lesions. The Egyptian Journal of Otolaryngology. 2013 Apr 1;29(2):93.
18. Dimitar D, Deliysk E, Hillman. State of the Art Laryngeal Imaging: Research and Clinical Implications. Curr Opin Otolaryngol H & N Surg. 2010 Jun;18(3):147-52.
19. Multi-Dimensional Voice Program 3.3. Software Informer. Retreived from May 8 2018. Available from https://multi-dimensional-voice-program.software.informer.com/
20. Tiger DRS Inc. Retreived from May 8 2018. Available from http://www.drspeech.com/
21. Voice and speech Systems. Retreived from May 2018. Available from https://www.vagmionline.com/
22. Romak JJ, Heur RJ, Hawkshaw MJ, Sataloff RT. The Clinical Voice Laboratory. In: Sataloff RT (Ed). Professional Voice - The Science and Art of Clinical Care. 4 th edition. San Diego, CA: Plural Publishing, 2017; p. 405-439.
23. Dixit VM, Sharma Y. Voice Parameter Analysis for the disease detection. Journal of Electronics and Communication Engineering. 2014 Jan;9(3):48-55.
24. Boersma P., Weenink D., “PRAAT: Doing phonetics by computer”, Version 4.3.14, Computer program, 2005.
25. Linear predictive coding - Wikipedia. (n.d.). Retrieved December 15, 2018, from https://en.wikipedia.org/wiki/Linear_predictive_coding#Overview
26. Fast Fourier transform - Wikipedia. (n.d.). Retrieved December 16, 2018, from https://en.wikipedia.org/wiki/Fast_Fourier_transform
27. Baken RJ, Orlikoff RF. Clinical measurements of speech and voice, 2nd edn. San Diego: Singular Thomson Learning; 2000. Hammarberg B. Clinical applications of methods for acoustic voice analysis. Int J Rehab Res. 1980; 3: 548-9.

28. Spectrogram - Wikipedia. (n.d.). Retrieved December 16, 2018, from https://en.wikipedia.org/wiki/Spectrogram
29. Titze IR. Principles of Voice Production. Iowa city, IA: National centre for voice and research;2000.
30. Hollien H, Shipp T. Speaking fundamental frequency and its disorders. London: Whurr Publishers; 2001.
31. Sulter AM, Wit HP, Schutte HK, Miller DG. A structured approach to voice range profile (phonetogram) analysis. Journal of Speech, Language, and Hearing Research. 1994 Oct;37(5):1076-85.
32. Inverse Square Law, Sound -wikipedia. (n.d). Retreived September 3 2017 from http://hyperphysics.phy-astr.gsu.edu/hbase/Acoustic/invsqs.html
33. Absolute threshold of hearing - Wikipedia. (n.d.). Retrieved December 1, 2018, from https://en.wikipedia.org/wiki/Absolute_threshold_of_hearing
34. Phonetogram - Glottopedia. (n.d.). Retrieved September 16, 2017, from http://www.glottopedia.org/index.php/Phonetogram
35. Spectrogram - Wikipedia. (n.d.). Retrieved December 16, 2019, from https://en.wikipedia.org/wiki/Spectrogram
36. Klingholz F. The measurement of the signal-to-noise ratio (SNR) in continuous speech. Speech Communication. 1987 Mar 1;6(1):15-26.
37. Brockmann-Bauser M, Drinnan MJ. Routine acoustic voice analysis: time to think again? validity and reliability of acoustic voice. Curr Opin Otolaryngol Head Neck Surg. 2011 Jun;19(3):165-70
38. Hillman RE, Kobler JB. Aerodynamic measures of voice production. In: Kent RD, Ball rvlJ (eds). Voice quality measurement. San Diego: Singular Publishing Group, 2000; P. 245-55.
39. Baken RJ, Orlikoff RF. Airflow and volume. In: Baken RJ, Orlikoff RF (eds). Clinical measurements of speech and voice. San Diego: Singular Thomson Learning, 2000; p. 337-91.
40. Eckel FC, Boone DR. The s/z ratio as an indicator of laryngeal pathology. Journal of Speech and Hearing Disorders. 1981 May;46(2):147-9.
41. Kitajima K, Fujita F. Estimation of subglottal pressure with intraoral pressure. Acta oto-laryngologica. 1990 Jan 1;109(5-6):473-8.
42. Titze IR. On the relation between subglottal pressure and fundamental frequency in phonation. The Journal of the Acoustical Society of America. 1989 Feb;85(2):901-6.
43. Hogikyan NO, Sethuraman G. Validation of instrument to measure voice-related quality of

life (V-ROOL). J Voice. 1999; 13: 557-69.

44. Jacobson BH, Johnson A, Grywalski C, Silbergleit A, Benninger MS. The Voice Handicap Index (VHI): Development and validation. Am J of Speech Lang Path. 1997; 6: 66-70.
45. Deary IJ, Wilson JA, Carding PN, MacKenzie K. VoiSS: a patient-derived voice symptom scale. Journal of psychosomatic research. 2003 May 1;54(5):483-9.

## MATERIALS & METHODS

| | | |
|---|---|---|
| Type of Study | : | Prospective Study |
| Source of Data | : | Young adults between 18 and 28 years of age, both males and females were selected from near by colleges. Informed consent was taken |
| Inclusion Criteria | : | Detailed history specifically about systemic diseases, upper respiratoty tract infection, tobacco and alcohol consumption and voice abuse was taken. They underwent detailed clinical examination.<br>Those who were screened by the above said procedure were selected for study. |
| Exclusion Criteria | : | Voice abuse<br>Hearing loss<br>Upper or lower respiratory tract infection<br>Any chronic systemic illness like tuberculosis, diabetes, hyper or hypothyroidism, Neurological disease etc. |
| Sample Size | : | In this at 5% level of significance and 3% margin of error the calculation was done based on the following formula :<br>$n = z^2p(1-p) /(d^2)$<br>where<br>Z= z statistic at 5% level of significance<br>d is margin of error<br>p is anticipated prevalence rate (50%) |
| Type of sampling/ technique | : | Judgement sampling |

*Data Collection Procedure*

**Sample Collection Setup**

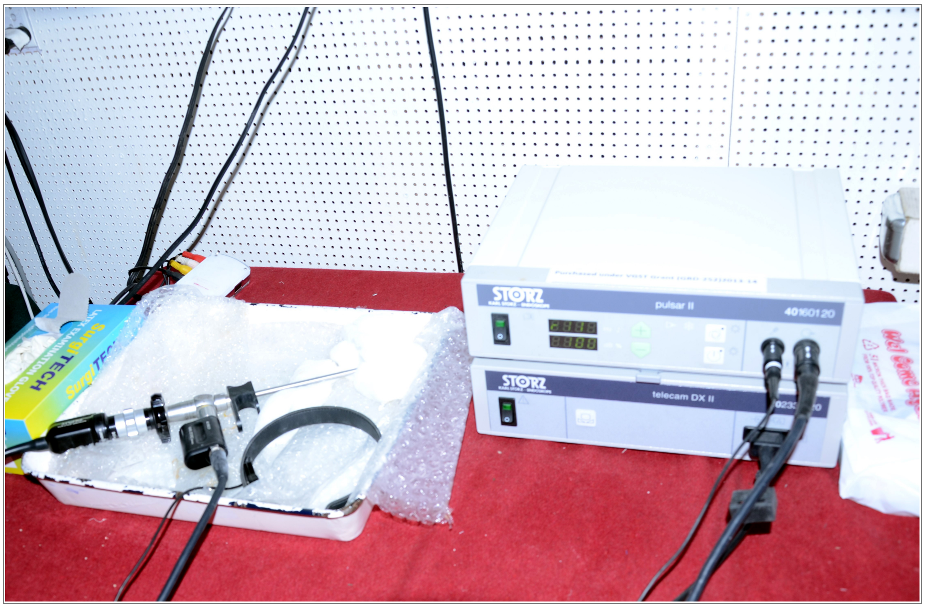



*Fig 21 - Voice Recording Set Up*

1. The voice samples were recorded in a sound treated room.
2. A regular Windows Desktop Computer was used.
3. A microphone, unidirectional microphone (Sony Audio-Technica 250XL) was used

*Recording of Voice Samples*

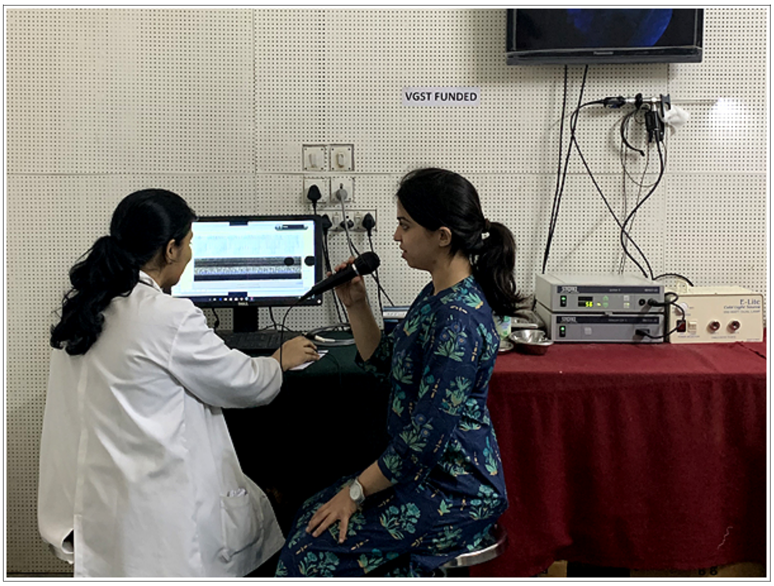



*Fig 22 - Recording of Voice*

The Microphone was held at a distance of 5cm in front of the lips and 3 cm above the breath stream. Each person was first trained to produce sustained vowel /a/ by the examiner herself through utterance of the voice at comfortable loudness and pitch. The sustained vowel, /a/ was recorded for minimum of 3 seconds using PRAAT[1] software.

A total of 1500 vowel samples were recorded. Only 1000 quality samples in terms of uniformity of volume and pitch were available because of technical reasons.

The 3 sec sustained vowels were then extracted in the spectrogram of PRAAT to get the most stable and uniform middle 1 sec segment.

*Extraction of Parameters*

The extracted audio clip was submitted to PRAAT[1] to get parameters

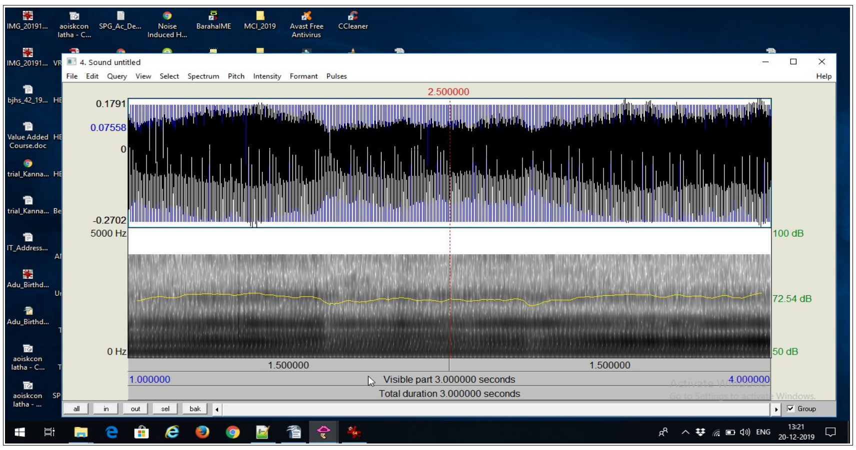



*Fig 23 - Three Seconds Clip*

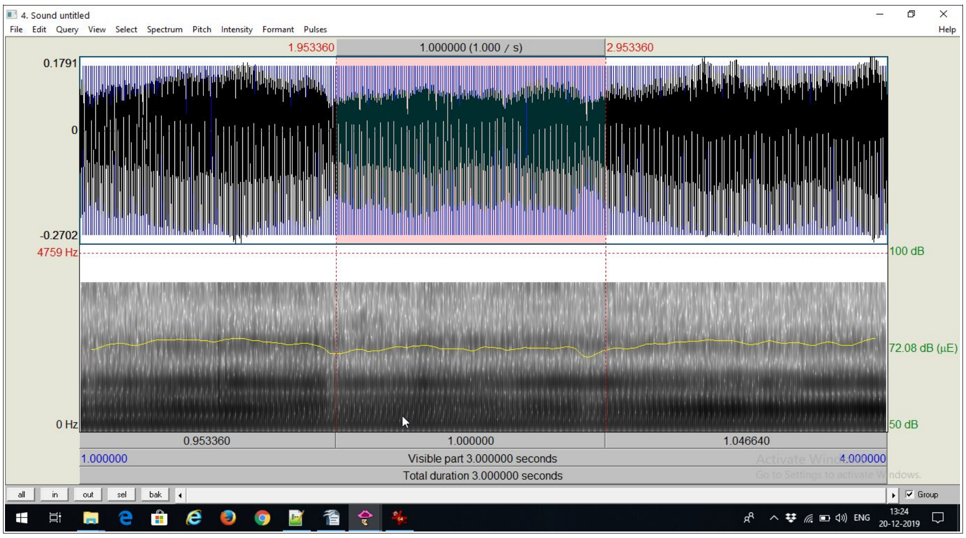



*Fig 24 - Selection of one Second Clip*

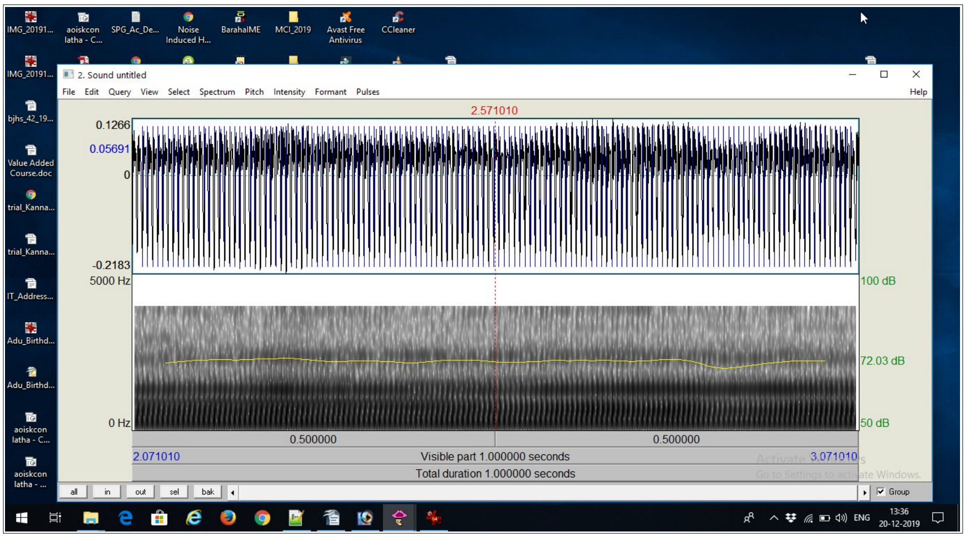



*Fig 25 - One Second Clip*

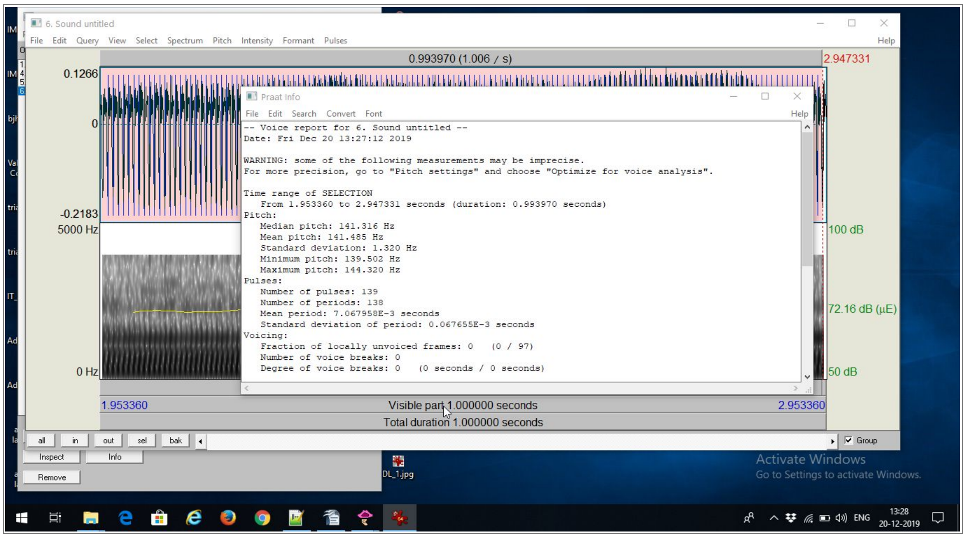



*Fig 26 - Voice Report*

To speed up and automate extraction of parameters, a *PRAAT Script* was written and utilised. The Script extracted, in a single go, parameters of batches of 20 voice clips in each from a folder in 1-2 minutes and pushed them to an excel sheet.

## PRAAT Script

```
#E:\Dr_Lathadevi\aaa_sounds\GROUP_A
#### GET DIRECTORY OF SOUND FILES
form GET VOICE REPORT
word DirectoryPath
endform
directory$ = directoryPath$
### WRITE CAPTIONS
writeInfoLine: "File Median pitch Mean pitch Standard deviation Minimum pitch Maximum pitch Number of pulses Number of periods Mean period Standard deviation of period Fraction of locally unvoiced frames Number of voice breaks Degree of voice breaks Jitter (local) Jitter (local, absolute) Jitter (rap) Jitter (ppq5) Jitter (ddp) Shimmer (local) Shimmer (local, dB) Shimmer (apq3) Shimmer (apq5) Shimmer (apq11) Shimmer (dda) Mean autocorrelation Mean noise-to-harmonics ratio Mean harmonics-to-noise ratio"
### CREATE A STRING OUT OF FILES LIST
strings = Create Strings as file list: "list", directory$ + "/*.*"
numberOfFiles = Get number of strings
### OPEN EACH FILE SEQUENTIALLY
for ifile to numberOfFiles
selectObject: strings
fileName$ = Get string: ifile
Read from file: directory$ + "/" + fileName$ ; Open files in praat
### OPEN SOUND EDITOR
View & Edit
files$=""
files$= "Sound " + replace$(fileName$,".wav","",4)
### ACCESS EDITOR OBJECT
editor: "'files$'"
Select: 0, 1.0
### CREATE VOICE REPORT OBJECT
voiceReport$ = Voice report
### GET PROPEETIES OF VOICE REPORT OBJECT
med_pitch = extractNumber (voiceReport$, "Median pitch: ")
mean_pitch = extractNumber (voiceReport$, "Mean pitch: ")
std_deviation = extractNumber (voiceReport$, "Standard deviation: " )
min_pitch = extractNumber (voiceReport$, "Minimum pitch: " )
max_pitch = extractNumber (voiceReport$, "Maximum pitch: " )
number_of_pulses = extractNumber (voiceReport$, "Number of pulses: ")
number_of_periods = extractNumber (voiceReport$, "Number of periods: ")
mean_period = extractNumber (voiceReport$, "Mean period: ")
standard_deviation_of_period = extractNumber (voiceReport$, "Standard deviation of period: ")
fraction_of_locally_unvoiced_frames = extractNumber (voiceReport$, "Fraction of
```

```
locally unvoiced frames: ")
number_of_voice_breaks = extractNumber (voiceReport$, "Number of voice breaks: ")
degree_of_voice_breaks = extractNumber (voiceReport$, "Degree of voice breaks: ")
j_1 = extractNumber (voiceReport$, "Jitter (local): ")
j_2 = extractNumber (voiceReport$, "Jitter (local, absolute): ")
j_3 = extractNumber (voiceReport$, "Jitter (rap): ")
j_4 = extractNumber (voiceReport$, "Jitter (ppq5): ")
j_5 = extractNumber (voiceReport$, "Jitter (ddp): ")
s_1 = extractNumber (voiceReport$, "Shimmer (local): ")
s_2 = extractNumber (voiceReport$, "Shimmer (local, dB): ")
s_3 = extractNumber (voiceReport$, "Shimmer (apq3): ")
s_4 = extractNumber (voiceReport$, "Shimmer (apq5): ")
s_5 = extractNumber (voiceReport$, "Shimmer (apq11): ")
s_6 = extractNumber (voiceReport$, "Shimmer (dda): ")
mean_autocorrelation = extractNumber (voiceReport$, "Mean autocorrelation: ")
mean_noise_to_harmonics_ratio = extractNumber (voiceReport$, "Mean noise-to-harmonics ratio: ")
mean_harmonics_to_noise_ratio = extractNumber (voiceReport$, "Mean harmonics-to-noise ratio: ")
### Formants Show Formants -> toggles
#Show formants
f0= Get first formant
f1= Get second formant
f2= Get third formant
f3= Get fourth formant
### PRINT FOR EACH FILE
appendInfoLine: fileName$,tab$,
... med_pitch,tab$,mean_pitch,tab$,std_deviation,tab$,min_pitch,tab$,max_pitch,tab$,
... number_of_pulses,tab$,number_of_periods,tab$,mean_period,tab$,standard_deviation_of_period,tab$,
... fraction_of_locally_unvoiced_frames,tab$,number_of_voice_breaks,tab$,degree_of_voice_breaks,tab$,
... j_1,tab$,j_2,tab$,j_3,tab$,j_4,tab$,j_5,tab$,
... s_1,tab$,s_2,tab$,s_3,tab$,s_4,tab$,s_5,tab$,s_6,tab$,
... mean_autocorrelation,tab$,mean_noise_to_harmonics_ratio,tab$,mean_harmonics_to_noise_ratio
### CLOSE THE EDIT OBJECT Show Formants -> toggles
Close
### ACCESS NEXT FILE
endfor
```

*Statistical Analysis Methods*

The extracted parameters were descriptively summarised using SPSS 20 Software[2]. Mean +/- Standard Deviation, Standard Deviation were used for continuous variable.. The number of percentage were used in the data summaries for categorical data. Wherever necessary graphs and diagrams were represented. Normality test was used for determination of distribution and range.

*References:*

1. Boersma P., Weenink D., "PRAAT: Doing phonetics by computer", Version 4.3.14, Computer program, 2005. IBM Support. IBM, Retreived on Jan, 3rd 2018, Available from https://www.ibm.com/support/pages/spss-statistics-20-available-download
2. IBM Support. IBM, Retrieved on Jan, 3rd , 2018, available from https://www.ibm.com/support/pages/spss-statistics-20-available-download

## OBSERVATION AND RESULTS

Out of 1000 voices, the number of male voice sample size was 458 (45.8%) and female voices were 542 (54.2%). This is depicted in the Pie chart below.


*Fig-27 - Sex Ratio*

The four parameters i.e. Pitch, Jitter, Shimmer and Harmonic to Noise Ratio of all the 458 males were statistically computed and the comprehensive values were derived. These are given in Table-1.

*Table-1: Parameters Among Males*

| Parameters | Mean Pitch | Jitter (DDP) | Shimmer (DDA) | Mean Harmonics-To-Noise Ratio |
|---|---|---|---|---|
| Mean | 137.0561 | 0.01149 | 0.083749 | 20.4810 |
| SD | 30.3518 | 0.01266 | 0.068467 | 4.84 |
| Mean +SD | 167.464421 | 0.2415 | 0.152216 | 25.32931 |
| Mean-SD | 106.708086 | 0.00117 | 0.015282 | 15.6339 |
| Maximum value | 278.1940 | 0.1537 | 0.45302 | 33.1290 |
| Minimum value | 76.432 | 0.00247 | 0.01181 | 0.711 |
| Median (middle) | 130.3605 | 0.0081 | 0.0600 | 21.3050 |
| Range | 106.7 to 167.4 | 0.00117 to 0.2415 | 0.01528 to 0.15282 | 15.634 to 25.32931 |
| 25TH Percentile | 119.8148 | 0.0060 | 0.0422 | 17.7950 |
| 75TH Percentile | 144.1345 | 0.0122 | 0.0942 | 23.6203 |

Similarly the values were derived for 542 females and are given in Table-2

*Table-2: Parameters Among Females*

| Parameters | Mean Pitch | Jitter (DDP) | Shimmer (DDA) | Harmonics-To-Noise Ratio |
|---|---|---|---|---|
| Mean | 234.2682495 | 0.01089 | 0.078905 | 21.73274 |
| Sd | 31.29034 | 0.00987 | 0.06143 | 5.013088 |
| Mean+ Sd | 265.5585 | 0.02076 | 0.140335 | 26.74582 |
| Mean-Sd | 202.97790 | 0.00103 | 0.017474 | 16.71965 |
| Maximum Value | 465.445 | 0.124 | 0.67366 | 33.8090 |
| Minimum Value | 85.69 | 0 | 0.02 | 2.17 |
| Range | 202.9779-265.5585 | 0.00103-0.02076 | 0.017474-0.140335 | 16.71965-26.74582 |
| 25th Percentile | 220.5995 | 0.0059 | 0.0401 | 19.0450 |
| 75th Percentile | 250.4635 | 0.0127 | 0.0945 | 25.2038 |

## PITCH

The computed values of Pitch are shown in Table-3

*Table – 3 : Pitch Values*

| Statistical Parameter | Male | Female |
|---|---|---|
| Mean | 137.0862538 | 234.2682495 |
| Sd | 30.37816721 | 31.29033971 |
| mean+sd | 167.464421 | 265.5585892 |
| mean-sd | 106.7080866 | 202.9779098 |
| Max Values | 278.194 | 465.445 |
| Min Values | 76.432 | 85.694 |
| Range of Pitch values | 106.70-167.46 | 202.97-265.55 |

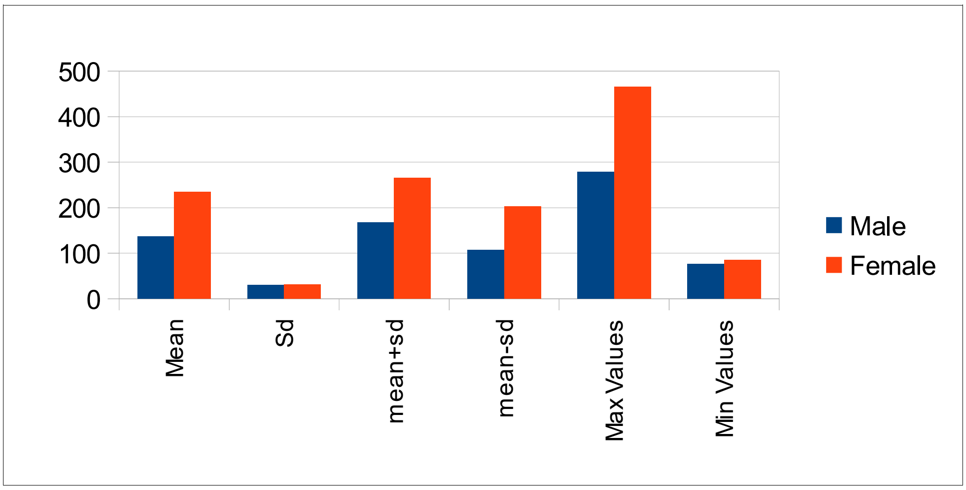



*Fig 28 - Pitch Values*

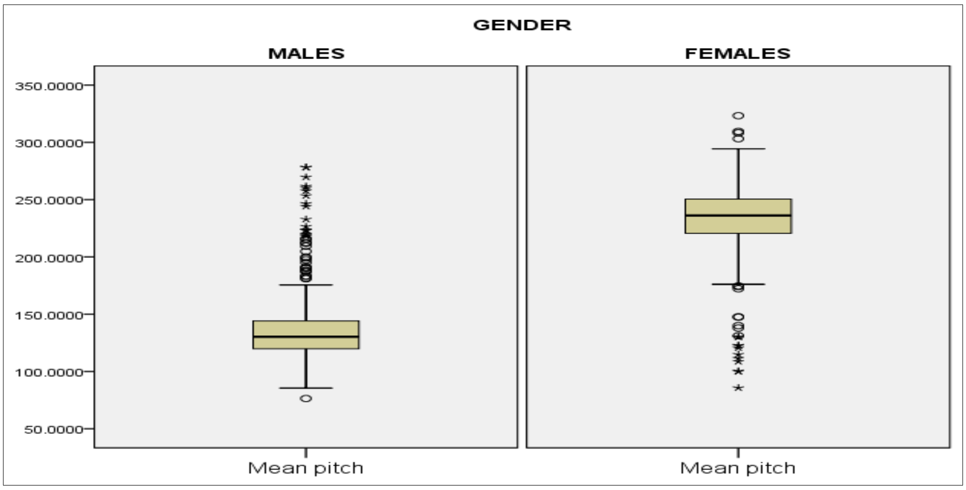



*Fig 29 - Box Plot to show Pitch in Males & Females*

Table – 4 shows Range of Pitch Values for both Females and Males

*Table -4 Pitch Values – Ranges*

| Gender | Min | Max |
|---|---|---|
| Males | 106.70 | 167.4 |
| Females | 202.97 | 265.55 |

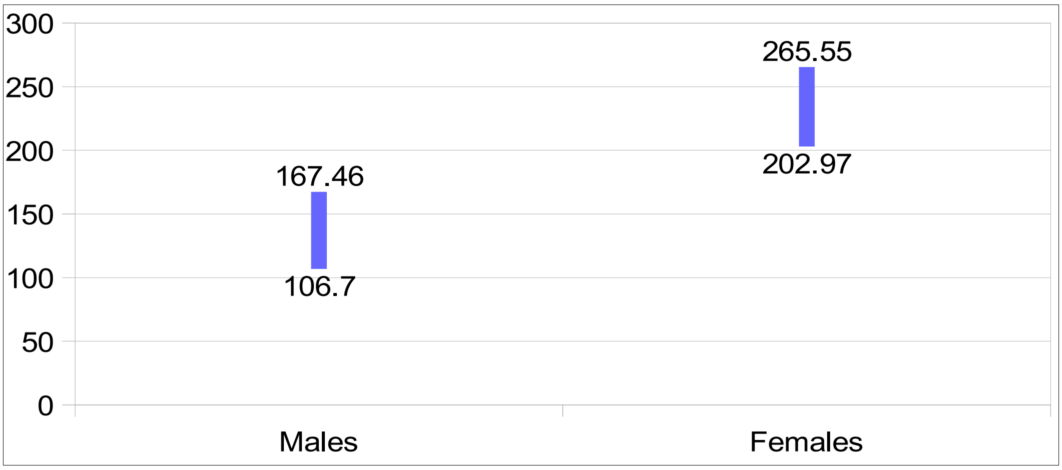



*Fig 30 - Pitch Ranges ( in Hz )*

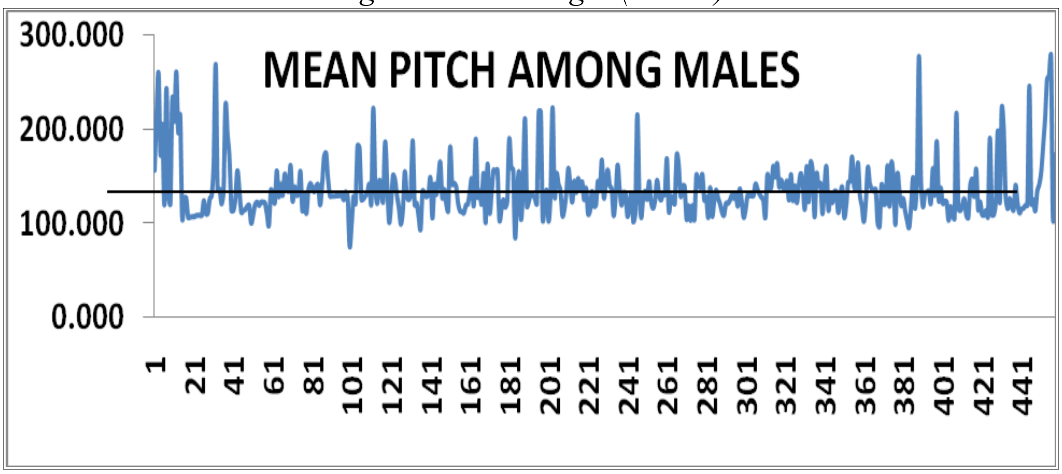



*Fig 31 - Mean Pitch among Males*

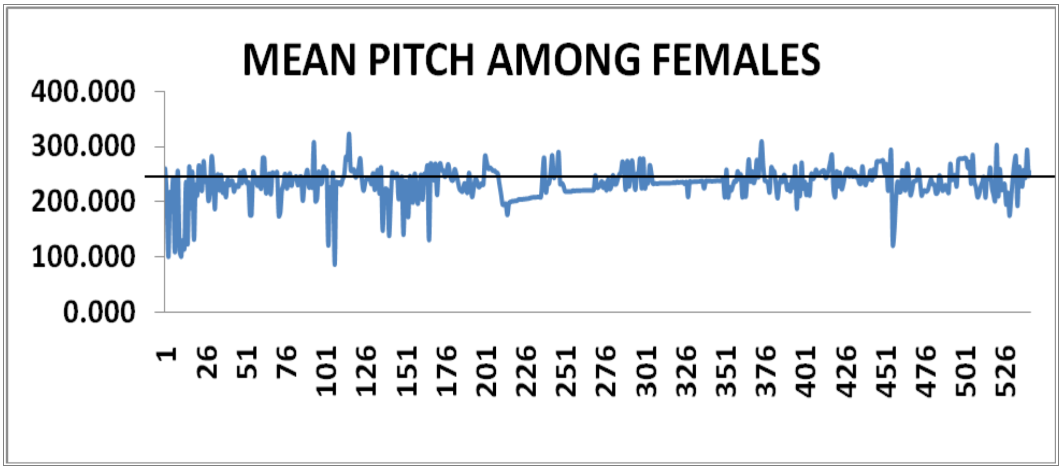



*Fig 32 - Mean Pitch among Females*

**The Pitch in females is consistantly higher than in males.**

## JITTER

The values of jitter (ddp) in males are depicted in table-5 below.

*Table – 5 : Jitter Values*

| Jitter Parameter | Male | Female |
|---|---|---|
| Mean | 0.0114 | 0.010895 |
| SD | 0.012662 | 0.009869 |
| Mean+SD | 0.02415 | 0.020764 |
| Mean-SD | 0.00117 | 0.00103 |
| Range of jitter | 0.00117-0.02415 | 0.001026-0.020764 |
| Max value | 0.1537 | 0.12455 |
| Minimum value | 0.00247 | 0.00229 |

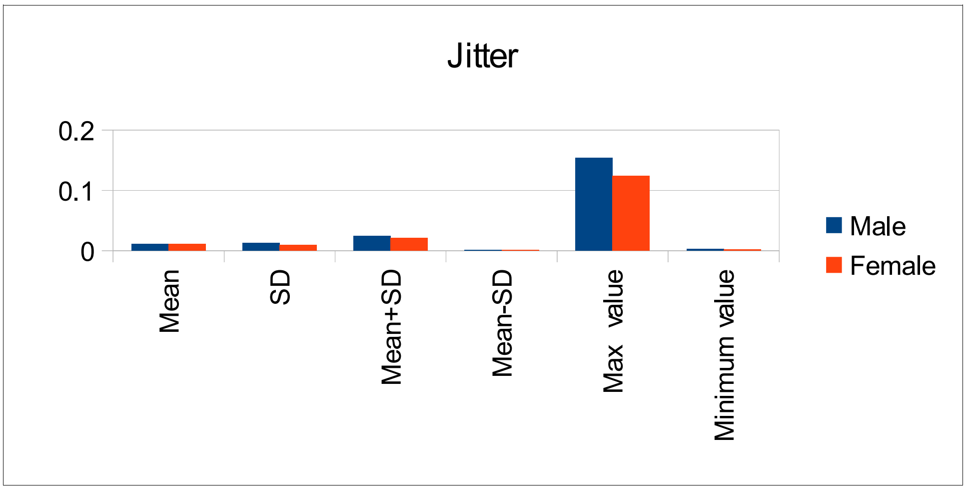



*Fig 33 - Jitter Values*

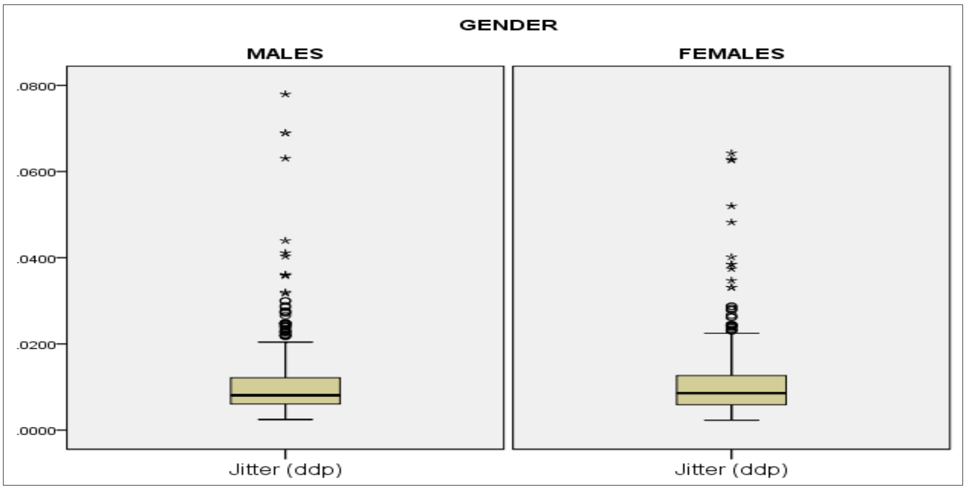



*Fig 34 - Box Plot to show Jitter Values*

**Jitter : Range**

*Table 6 - Jitter : Ranges*

| Gender | Min | Max |
|---|---|---|
| Males | 0.00117 | 0.02415 |
| Females | 0.00103 | 0.02076 |

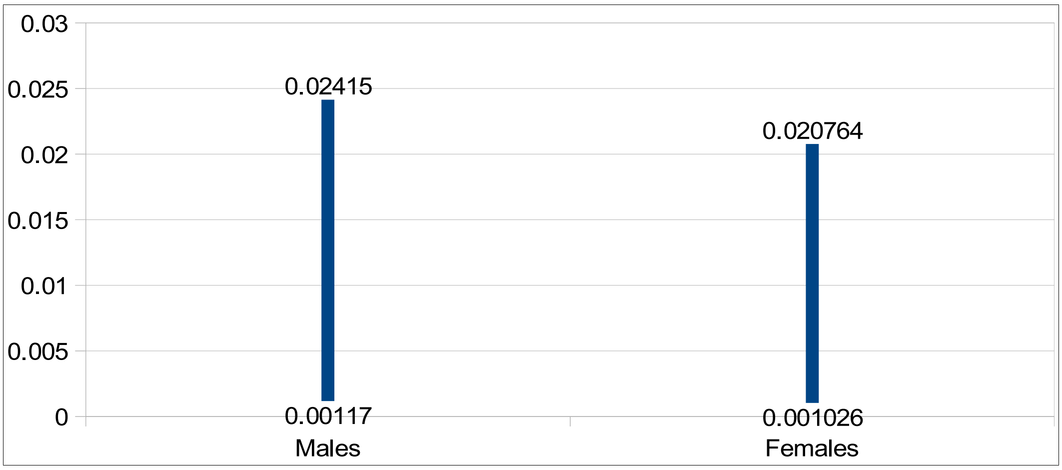



*Fig 35 - Jitter : Ranges*

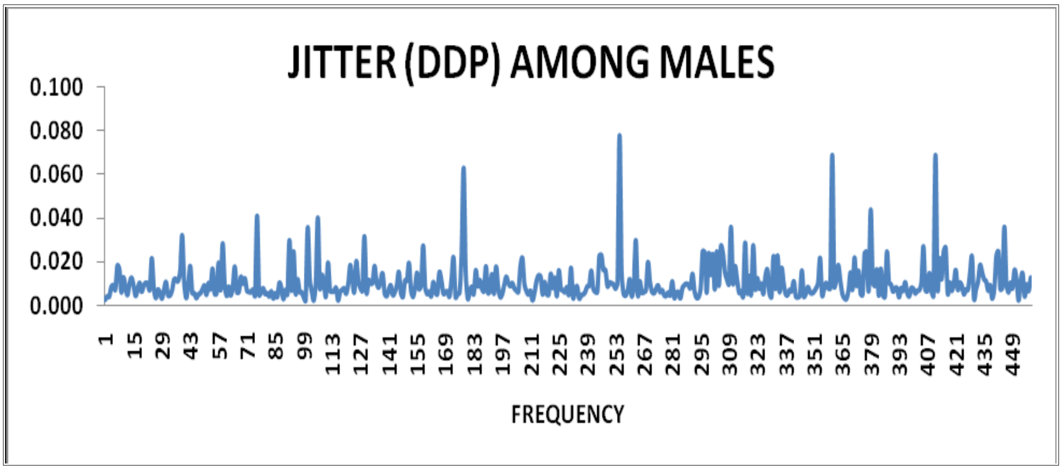



*Fig 36 - Jitter Values in Males*

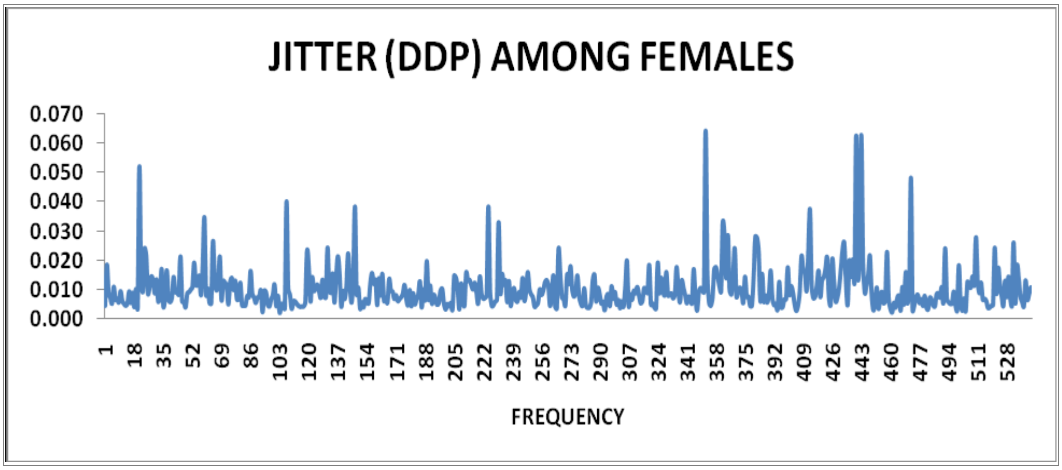



*Fig 37 - Jitter Values in Females*

**Jitter Range is almost the same in both males and females**

## SHIMMER

*Table – 7 : Shimmer Values*

| SHIMMER Parameter | Male | Female |
|---|---|---|
| Mean | 0.083749 | 0.078905 |
| SD | 0.068467 | 0.0023 |
| Mean+SD | 0.152216 | 0.140335 |
| Mean-SD | 0.015282 | 0.017474 |
| Maximum value | 0.45302 | 0.67366 |
| Minimum value | 0.01181 | 0.01742 |
| Range of Shimmer | 0.015282-0.15282 | 0.017474-0.140335 |

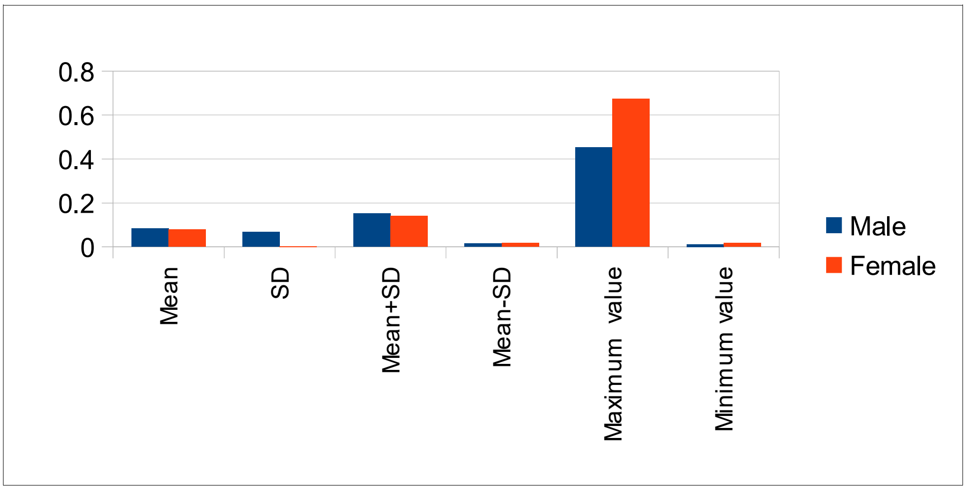



*Fig 38 - Shimmer Values*

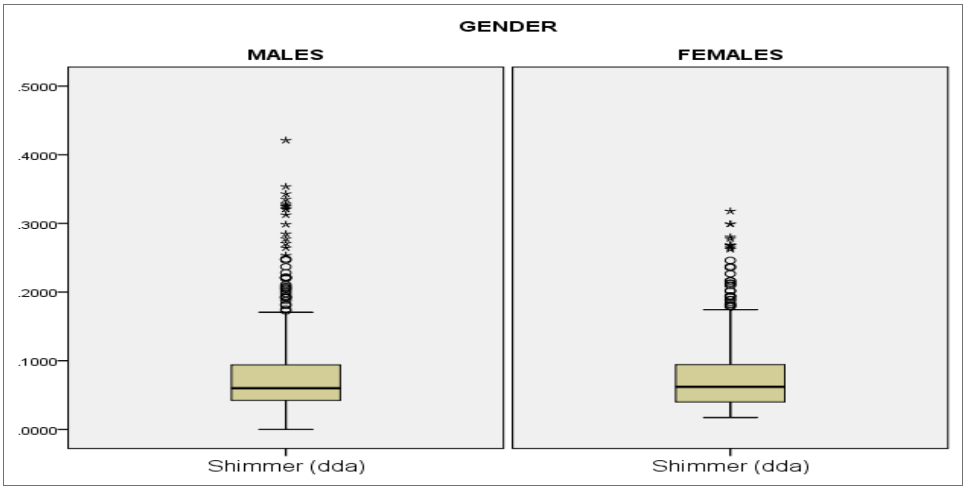



*Fig 39 - Box Plot to show Shimmer Values*

**ShimmerRange**

*Table 8 - Shimmer : Ranges*

| Gender | Min | Max |
|---|---|---|
| Male | 0.015282 | 0.15282 |
| Female | 0.017474 | 0.140335 |

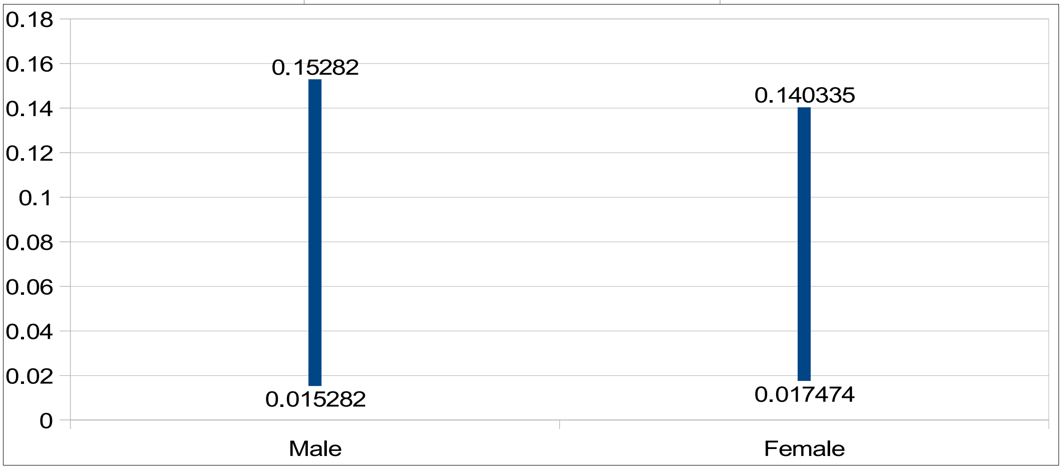



*Fig 40 – Shimmer Ranges in Males & Females*

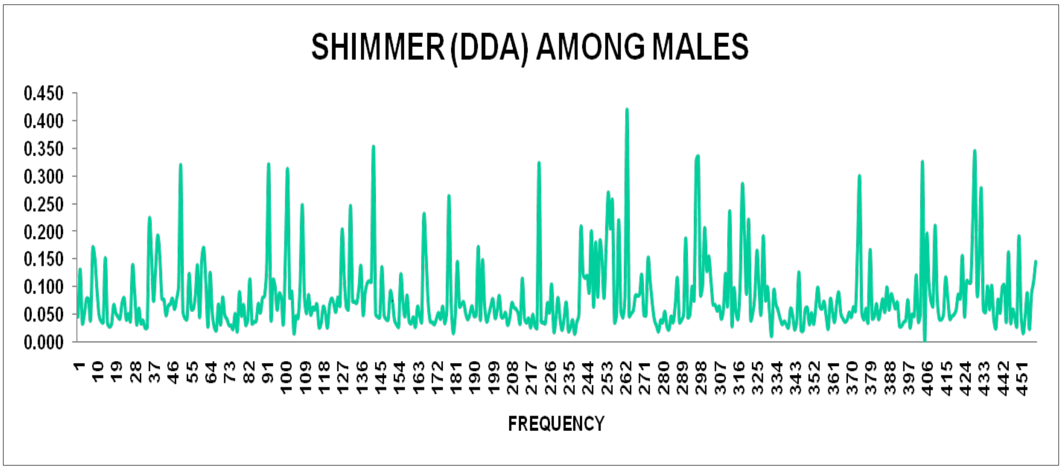



*Fig 41 - Shimmer Ranges in Males*

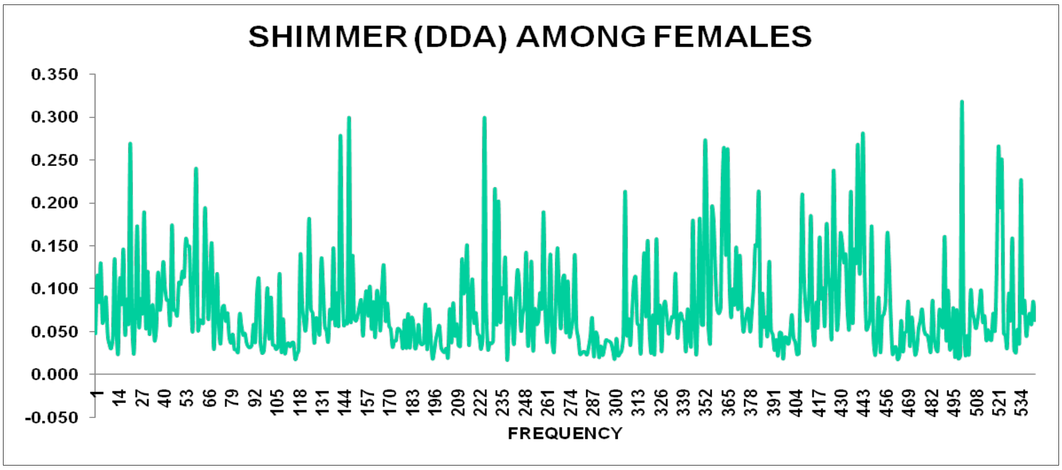



*Fig 42 - Shimmer Ranges in Females*

**There is no much difference in Shimmer between Males and Females**

## HARMONIC TO NOISE RATIO - HNR

*Table 9 – HNR Values*

| HNR Parameters | Male HNR | Female HNR |
|---|---|---|
| Mean | 20.481 | 21.7327 |
| SD | 4.824 | 5.013088 |
| Mean+SD | 25.32931 | 26.74582 |
| Mean-SD | 15.6339 | 16.71965 |
| Minimum | 0.711 | 2.719 |
| Maximum`` | 33.129 | 33.809 |
| Range of HNR | 15.6339 to 25.32931 | 16.71965-26.74582 |

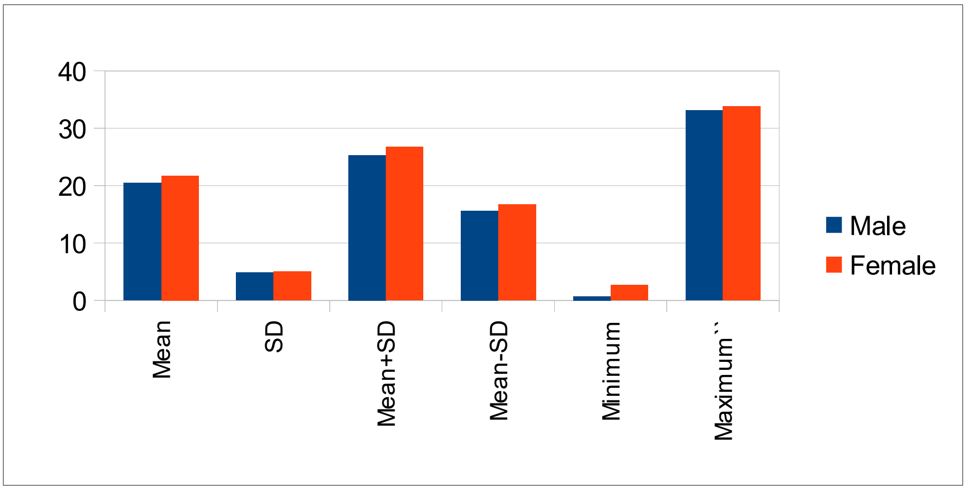



*Fig 43 - HNR Values*

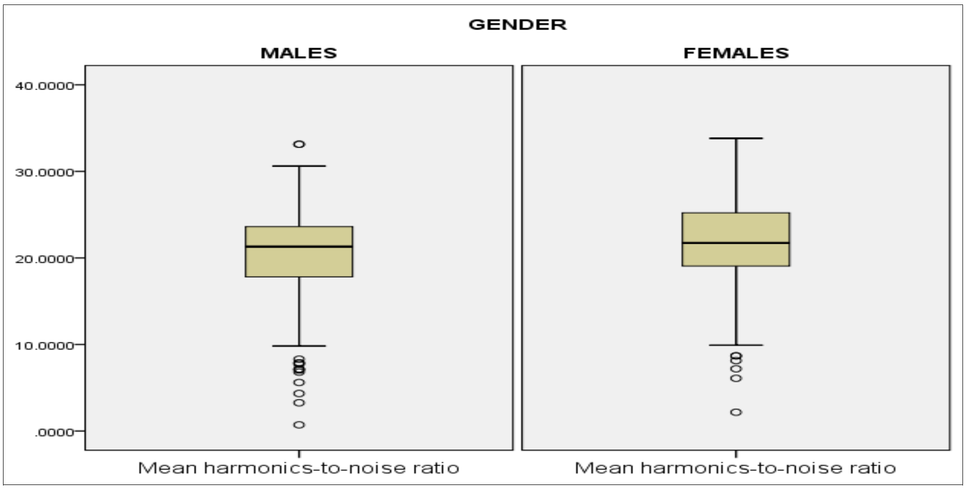



*Fig 44 - Box Plot to show HNR Values*

**Harmonic to noise ratio -Range**

*Table 10 - HNR Ranges*

| Gender | Min | Max |
|---|---|---|
| Male | 15.6339 | 25.32931 |
| Female | 16.71965 | 26.74582 |

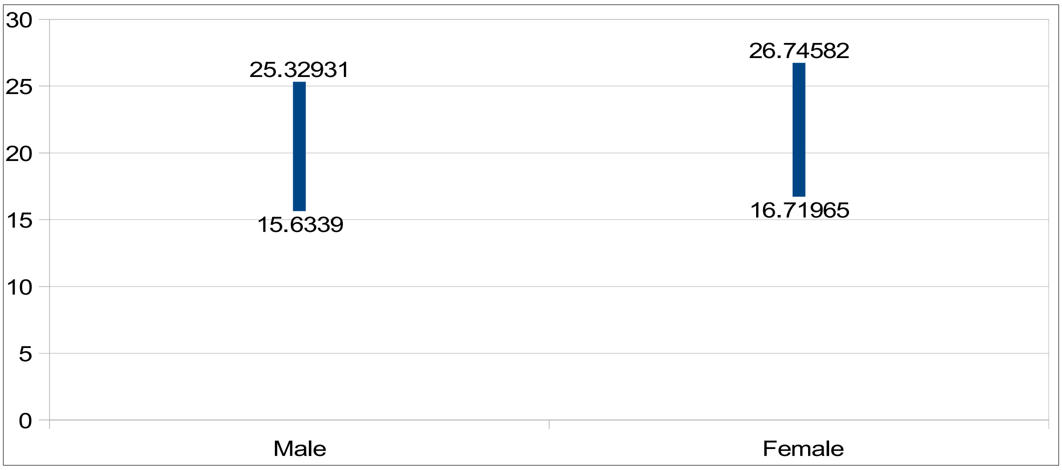



*Fig 45 - HNR Range*

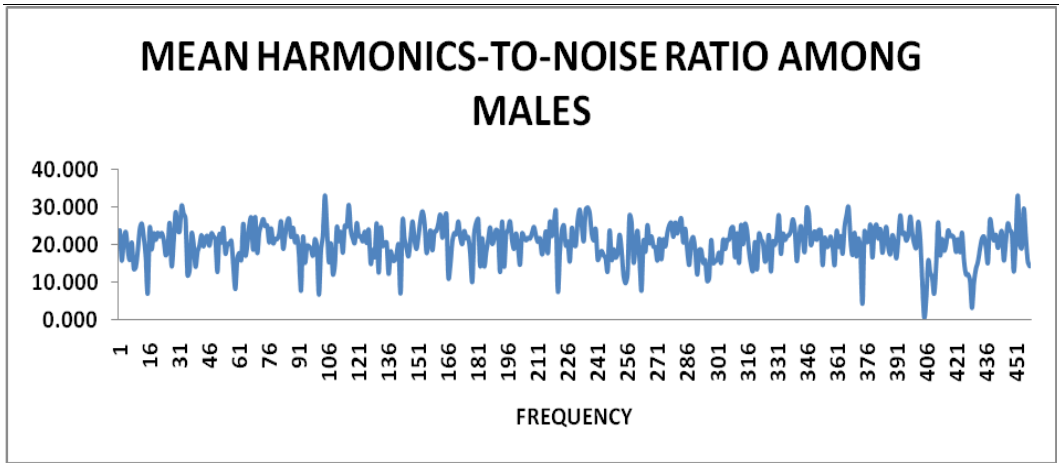



*Fig 46 - Mean HNR in Males*

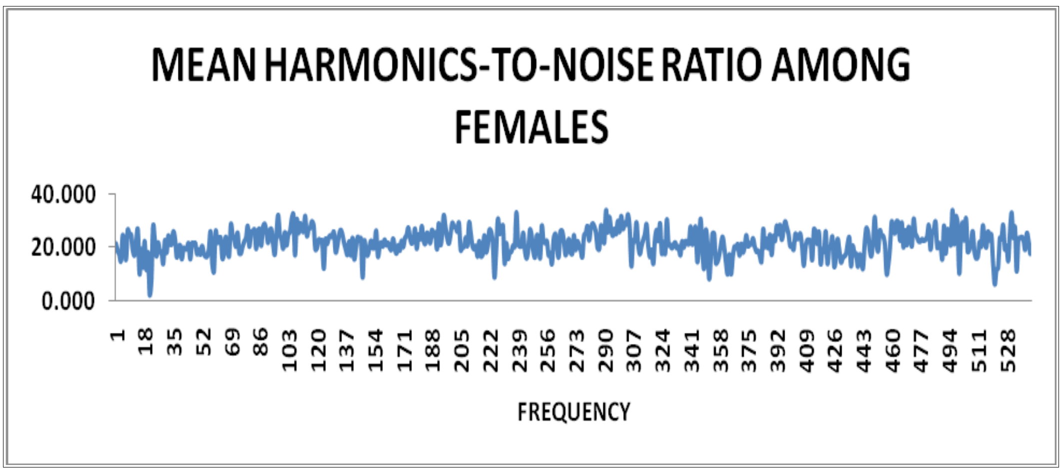



*Fig 47 - Mean HNR in Females*

**Whether male or female the Harmonic to Noise Ratio (HNR) is almost the same.**

## DISCUSSION

Our objective was to identify and standardise the parameters of normal voice by a simple, easier and non-invasive method so that this becomes a handy tool for day to day use to the clinical practitioner who addresses vocal disorders.

The perceptive methods have been subjective, difficult to quantify, document and not reproducible.[1]

Other non-subjective methods wherein instruments are used are invasive, time consuming and need expensive equipment.[2,3]

With stroboscopy analysis alone it is difficult to diagnose disorders like spasmodic dysphonia.[4]

As a non-invasive, objective, easier method acoustic analysis proves valuable in diagnosis and management of voice disorders.[5]

Acoustic analysis requires a simple computer, a microphone and a voice analysis software.[6] Worldwide acoustic analysis became a standard practice and many researchers began to analyse normal and abnormal voices and soon came to know that voice is multidimensional.

Pitch Jitter, Shimmer and Harmonics to noise Ratio are the most commonly selected parameters[6,7,8,9]

It was evident that values of the same parameters were different in different situations. For e.g., in different ages, sexes, durations of the day, emotional factors, regions, types of program, algorithims, hardware used for analysis etc. Hence most of the authors felt that voice evaluation by acoustic analysis require standardisation of the normal voice parameters.[10]

When we tried to compare our values with that of other studies, it was found that most of the data were calculated in different ways. For e.g., Jitter can be measured as Jitter%, Jitter ddp, absolute Jitter, local jitter etc. Similarly Shimmer can be measured as dda, Shimmer %, Shimmer Db, absolute Shimmer etc. Hence comparision becomes difficult. There are some studies given below which we tried to compare with our study. For example, Ana Clara Felippe et Al.[10], Kirt Aries[11] and Grahaam Williamson[12] considered jitter in terms of % jitter. Deqhan et Al[15] considered Average jitter. Simone[13] took jitter factor for calculation. The author of this study considered Jitter(ddp).

**PITCH**

The following Table shows comparision of Pitch Values

*Table 11 – Comparision of Pitch Values*

| Author | Males | Females |
|---|---|---|
| Grahaam Williamson[12] | 128 | 225 |
| Simone[13] | 127.6 | 215.45 |
| Bonzi[17] | 128 | 225 |
| Kirt Aries[11] | 130.6 | 218.38 |
| Chen chi Wang[14] | 118.3 | 203.2 |
| Deqhan et Al[15] | 112 | 214.64 |
| Lathadevi HT | 137.05 | 234.26 |

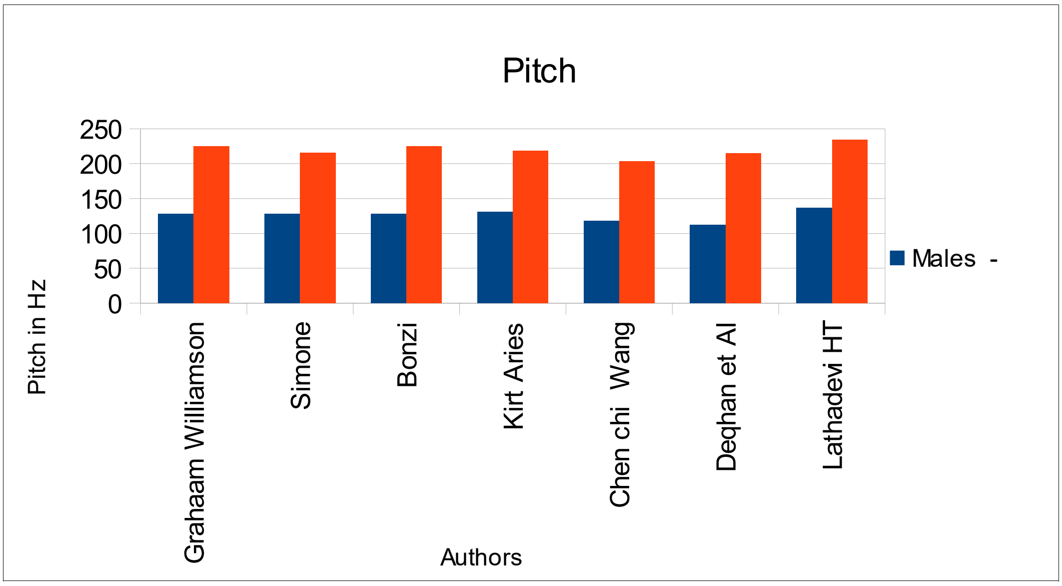



*Fig 48 - Pitch Comparision*

We could compare Pitch Values with quite many autthors(Grahaam Williamson[12], Simone[13], Bonzi[17], Kirt Aries[11], Chen chi Wang[14], Deqhan et Al[15]).

Ana Clara Felippe et Al[10] tried to give standard values for jitter, shimmer, fundamental frequency and HNR studying 20 male and 20 female adults by using vowel 'a'. Their values are :

1. Jitter 0.49%
2. Shimmer 0.22dB
3. Fundamental frequency 119.84 Hz
4. HNR 9.56

Since their values are different from those in literature they opine that it is important to standardise normative data.

**JITTER**

The following table and graph depict the values.

*Table 12 – Comparision of Jitter Values*

| Author | Males | Females |
|---|---|---|
| Bonzi | 0.36 | 0.3 |
| Deqhan et Al | 0.23 | 0.22 |
| Lathadevi HT | 0.01149 | 0.01089 |

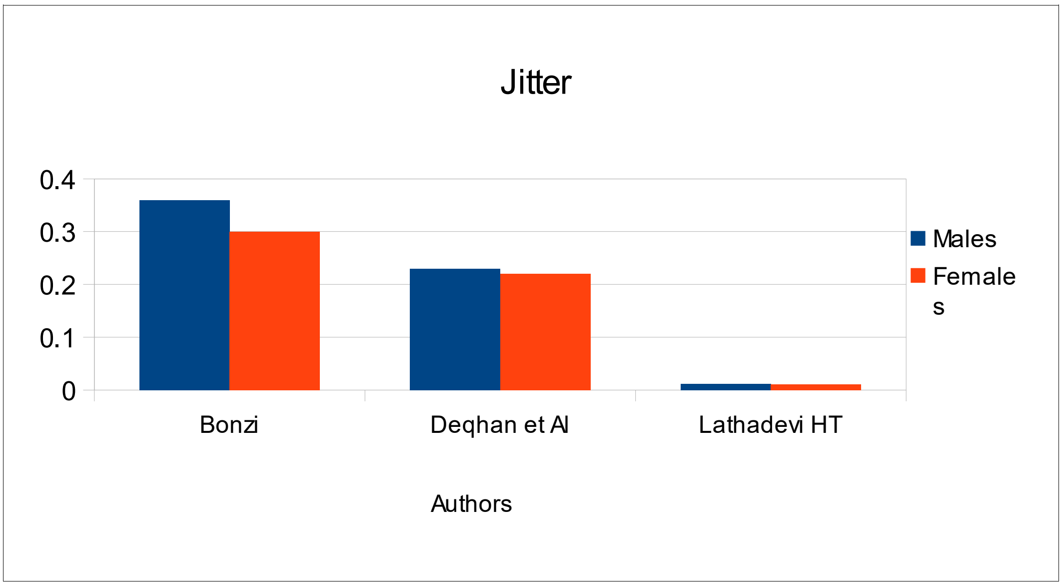



*Fig 49 - Jitter Comparision*

As such among all, only two authors( Bonzi[17] and Deqhan et Al[15]) have considered Jitter values comparable to ours. They show that our jitter values are quite less than them. When compared with other studies the jitter values in our study are less than those of many authors.[15,17,18] ( Jitter – Males : 0.01149, Females : 0.01089). For example in studies by Deqhen et Al Jitter was 0.23 for males and 0.22 for females.

**SHIMMER**

The following table and graph show the comparision.

*Table 13 – Comparision of Shimmer Values*

| Author | Males | Females |
|---|---|---|
| Ana Clara | 0.227 | 0.222 |
| Kirt Aries | 0.23 | 0.25 |
| Lathadevi HT | 0.08375 | 0.0789 |

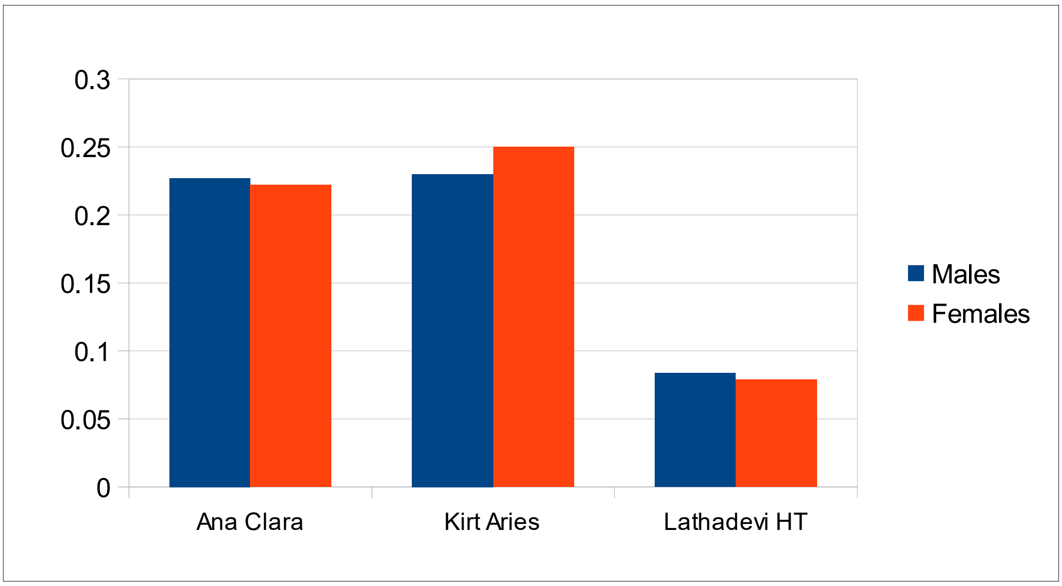



*Fig 50 - Shimmer Comparision*

**Our Shimmer values are comparable but low to those of other two authors(Ana Clara[10], Kirt Aries[11]).**

**HNR**

The following table shows comparsion of HNR

| *Table 14 – Comparision of HNR* | | |
|---|---|---|
| **Author** | **Males** | **Females** |
| Ana Clara | 9.56 | 10.9 |
| Grahaam Williamson | 20 | - |
| Bonzi | 20 | 21.796 |
| Chen chi  Wang | 8.2 | 12.2 |
| Deqhan et Al | 18.42 | 18.81 |
| Lathadevi HT | 20.481 | 21.73274 |

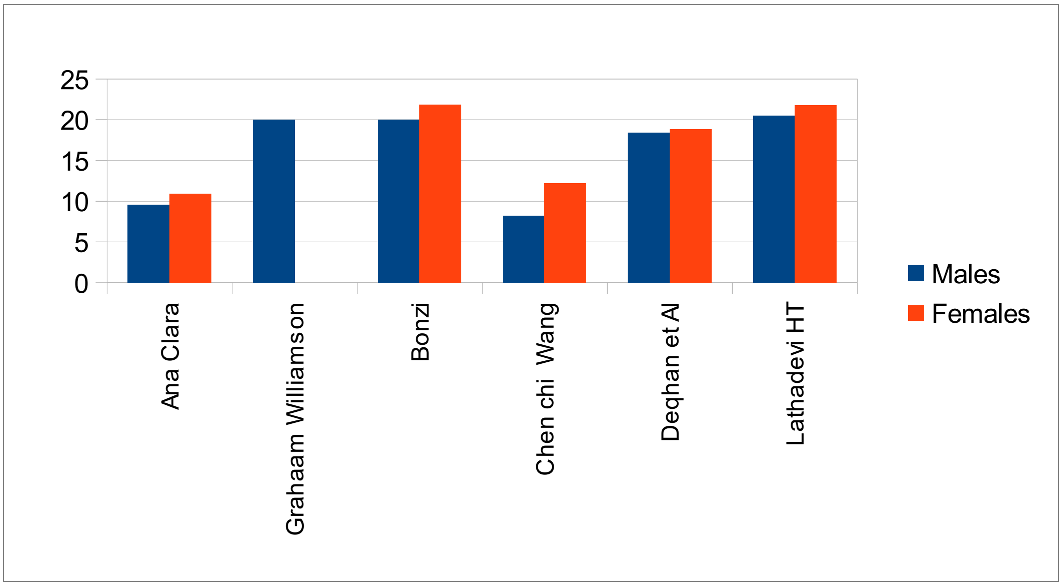



*Fig 51 - HNR Comparision*

We could compare HNR with number of authors (Ana Clara Fillippe[10],Grahaam Williamson[11], Simone[13], Bonzi[17], Chen chi  Wang[14], Deqhan et Al[15]) The HNR is quite similar in our study ( 20.48dB for males and 21dB for females) to those of Bonzi[17]( 20dB for males and 21dB for females) and Deqhan et Al[15]( 18.42dB for males and 18.81dB for females). However, HNR was less than our study in the studies of Chen Chi Wang[14] (8.2dB for males and 12.2dB for females) and Ana Clara Fillippe[10](9.56dB males and 10.9dB females).

Di Niccola et Al[16] have worked to check the possibilities, reliability, and  also the limitations of a procedure that was objective and parametric and evaluated the normal and pathological voices. Here, HNR was analysed for determining the relationship between noise and harmonics using 208 subjects of which 60 were normal and 148 were abnormal. The results concluded that voice analysis is not only simple, but highly sensitive. They concluded in so many words - “For the data obtained to be valid, a necessary condition is the application of a strict, precise, correct sampling and analysis method following well-defined rules. Finally, the values obtained can serve as a basis for the construction of an objective instrumental voice measurement protocol that can be used in forensic evaluation of dysphonia. Standardization of the regulations is essential to such a project.”

As per the opinion of Bonzi et Al[17] acoustic analysis is one of the major advances in the study of voice, increasing the accuracy of diagnosis in this area. They felt that normal values as standards are important and necessary to guide voice professionals. Using Praat they analyzed 72 voices of female and male voices among Argentinian Spanish speaking population. Their values were :

1. Pitch 128 Hz
2. Jitter 0.36+/- 0.10
3. Shimmer 2.7+/- 1.1
4. HNR 20+/-2

They felt that the region where the study is done has important influence on the results and this kind of study is useful in comparing normal and abnormal voices of people from different regions. Methodology of sample collection is of paramount importance as the values of voice parameters depend on the prior training of the individual, type and make of microphone used, distance between the mouth and the microphone, type of hardware and software used, sound treated room etc.

Kirt Delovino et Al[11] opine that “despite the accuracy and reliability of each machine, authors have agreed to standardize normative data individually due to a number of factors that may cause variations among each system. These possibilities include the type of programming of the acoustic analysis software, the use of recording criteria, type of microphone and other devices used in voice recording.”

The effect of recording quality on the analysis of voice and speech was studied by Vogel et Al[18]. They opine that acoustical parameters depend on environment, expertise of the clinician and the parameters extracted. According to them the best quality can be obtained using a sound treated room, recording on a hard disc, an dedicated mixer and a good microphone.

Graham Williamson[12] in his article states: “It is difficult to be precise about norms for acoustic measures such as jitter, Shimmer, noise-to-harmonics ratio and fundamental frequency. There are many factors which militate against declaring all-encompassing norms. Some of these are person-specific, gender and age differences), cultural (e.g. what north Americans may consider to be within normal limits may be different from what north Koreans consider to be typical), and related to the testing environment (e.g. variation in the equipment used, and, importantly the use of different algorithms in the software programs which are used to make the measurements). Measures of jitter and Shimmer using one software program cannot always be compared directly with measures made by another software program."

Fernandez Liesa et Al[19] used Dr. Speech Science software and analysed 154 voices of healthy adults. Their value of Mean F0 was 201 Hz in women and 129 Hz in men. According to age, the F0 increased in men but not so in women as changes in F0 were not statistically significant in women. They opine that age, sex and F0 did not significantly influence jitter, shimmer or HNR.

Wang et Al[14] used computer speech lab Aerophone system manufactured by Kay Elemetrics Corp to establish parameters for normal individuals(both male and female, 45 each). The fundamental frequency was 118 Hz for males and 213 Hz for females. However there was no gender difference in jitter though shimmer and H/N ratio were variable in different genders and age groups.

Dehqan et Al[15] in Iran did a study to identify parameters of acoustic analysis for normal individuals (45 males and 45 females). Their values were - F0 : female 214, male 112; shimmer : female 1.21, male 1.22; jitter : females 0.22, males 0.23. HNR was greater in females.

A comparision between normal and abnormal voices was done by Di Nicola[16] and colleagues using computerised digital sonography. They could identify a significant difference in HNR between normal and abnormal voices.

Haldun Oguz[20] compared Praat and MDVP (Multi-Dimensional Voice Program) and found significant differences in Jitter and HNR. Maryn et al[21] compared jitter and Shimmer measures using both MDVP and Praat programs. The authors noted that MDVP yielded higher values than Praat. They conclude that one can not compare jitter and shimmer outcomes across systems and programs.

Steven Bielamowicz et Al[22] have compared perturbation measures from different systems like CSpeech, SoundScope, Hand Marking Voice Analysis system and Computerized Speech Laboratory. The results were different for different systems and made the authors to opine that different systems yield different units.

Toran et Al[6] analysed voices of vocal polyp patients pre and post operatively. There were changes in parameters that indicated improvement in the voice post-operatively. Authors opined that objective analysis can provide a tool to clinicians for a better understanding of quality of voice.

A review was done by Hartl et Al[23], for providing update on current techniques of dysphonia evaluation in routine clinical practice. They concluded that the objective evaluation of the voice parameters like fundamental frequency and the spectral characteristics of voice has the advantage of being simple to perform, reproducible and quantifiable. But, during evaluation of severe dysphonia, automatic measurements need to be analyzed with caution as the computer algorithms being designed for voices retaining a certain periodicity. They concluded that all of these types of analysis are complementary, informing as to different aspects of vocal quality and laryngeal function. No one measurement alone can diagnose or characterize dysphonia.

Going through the above it is clear that different authors have attempted analysis in a different environment, on different subject groups, using different equipment and software and have given different values for different parameters.

*References :*


1. Kreiman J, Gerratt BR, Kempster GB, Erman A, Berke GS. Perceptual evaluation of voice quality: Review, tutorial, and a framework for future research. Journal of Speech, Language, and Hearing Research. 1993 Feb;36(1):21-40.
2. Boone DR, McFarlane SC, Berg SLV, Zraik RI. The voice and Voice Therapy. 8th edition, Boston: Allyn and Bacon; 2010.
3. Patel RR, Harris SM, Halum SL. Objective voice Assessment. In: Benninger M. (Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1st Ed. New Delhi: The Health Sciences Publisher, 2016; p. 155-66.
4. Woo P. Stroboscopy and High speed video examination of Larynx.. In: Benninger.MS.(Ed). Sataloff's Comprehensive textbook of Otolqaryngology Head and Neck surgery. 1 st edition. New Delhi, The Health Sciences, 2016; p.23-33.
5. Baken R, Olikoff R. Clinical measurement of speech and voice. 2 nd ed, Singular Thomson learning: 2000.
6. Toran KC, Lal BK. Objective voice analysis for vocal polyps following microlaryngeal phonosurgery. Kathmandu University Medical Journal. 2010; (8) 30 : 185-189.
7. Viktoras S, Ingrida U. Perceptual and acousticassessment of voice pathology and efficacy of endolaryngeal phonomicrosurgery. J of Voice. 2005;(19):138-45.
8. Geovani A, Revis J, Triglia JM. Objective, aerodynamic and acoustic measurement of voice improvement after phonomicrosurgery. Laryngoscope. 1999;(109):656-60.
9. Ping Yu, Maurice Ouaknine, Joana Revis, and Antoine Giovanni. Objective Voice Analysis for Dysphonic Patients: A Multiparametric Protocol Including Acoustic and Aerodynamic Measurements. Journal of Voice. 2006; (15) 4:529–542.
10. de Felippe AC, Grillo MH, Grechi TH. Standardization of acoustic measures for normal voice patterns. Brazilian Journal of Otorhinolaryngology. 2006 Sep 1;72(5):659-64.
11. Delovino KA, Casile RU, Hawson F. Vocal Acoustic Measures of Asymptomatic Filipino Young Adults at a Private Tertiary Hospital in Quezon City-A Pilot Study. Philippine Journal of Otolaryngology Head and Neck Surgery. 2012 Dec 1;27(2):7-11.
12. Williamson G. Acoustic Measures (Norms). Voice. [internet] 01 February 2014. Viewed on jan 2017 jan 5th. Available from http://www.sltinfo.com/acoustic-measures-norms/
13. Simone AA, Jose CP, Marcelo OR. Standardization of acoustic measures of the normal voice. Brazilian J Otolaryngol. 2002; 68:4(14) :540-44.
14. Wang CC, Huang HT. Voice acoustic analysis of normal Taiwanese adults. J Chinese Med Ass. 2004 Apr;67(4):179-84.

15. Dehqan A, Ansari H, Bakhtiar M. Objective voice analysis of Iranian speakers with normal voices. Journal of Voice. 2010 Mar 1;24(2):161-7.
16. Di VN, Fiorella ML, Luperto P, Staffieri A, Fiorella R. Objective evaluation of dysphonia. Possibilities and limitations. Acta Otorhinolaryngologica Italica. 2001 Feb;21(1):10-21.
17. Bonzi EV, Grad GB, Maggi AM, Muñóz MR. Study of the characteristic parameters of the normal voices of Argentinian speakers. arXiv preprint arXiv:1508.06226. 2014 ;6 (1):23-25.
18. Vogel AP, Morgan AT. Factors affecting the quality of sound recording for speech and voice analysis. International journal of speech-language pathology. 2009 Jan 1;11(6):431-7.
19. Fernández RL, Damborenea DT, Rueda PG, Leache JP, del Alamo Campos MA, Llorente EA, Naya MG. Acoustic analysis of the normal voice in nonsmoking adults. Acta otorrinolaringologica espanola. 1999 Mar;50(2):134-41.
20. Oğuz H, Kiliç MA, ŞAFAK MA. Comparison of results in two acoustic analysis programs: Praat and MDVP. Turkish Journal of Medical Sciences. 2011 Sep 7;41(5):835-41.
21. Maryn, P, Corthals J, Vanderbeke, E. Vanwynsberge M, De Bodt, P, Cauwenberge V. Intersystem and interprogram difference in acoustic perturbation measurement: a comparison between MDVP and Praat. In: Paper presented in the7th Pan European Voice Conference (PEVOC7), Groningen, The Netherlands, 29thAugust–1st September, 2007.
22. Bielamowicz S, Kreiman J, Gerratt BR, Dauer MS, Berke GS. Comparison of voice analysis systems for perturbation measurement. Journal of Speech, Language, and Hearing Research. 1996 Feb;39(1):126-34.
23. Hartl DM, Hans S, Crevier LB, Laccourreye O, Vaissiere J, Brasnu D. Dysphonia: current methods of evaluation. InAnnales d'oto-laryngologie et de chirurgie cervico faciale: bulletin de la Societe d'oto-laryngologie des hopitaux de Paris 2005 Sep; 122 (4):163-172.

## SUMMARY

Voice can be objectively analysed using Acoustic Parameters like mean Pitch, Jitter, Shimmer and Harmonic Noise Ratio. Most of the studies show that normal voice parameters depend on gender, region, methodology of the voice collection, software and the hardware used, different algorithms used for calculations and the set up etc. Hence every institution should standardise the method of acoustic analysis for its own consumption. For the purpose we have created a huge database of voices of normal young adults.

In our study we have tried to identify normative acoustic parameters for normal young adults. The normative values in our study are :

| | | *Male* | *Female* |
|---|---|---|---|
| Mean Pitch | : | 137.0561 | 234.27 |
| Mean Jitter | : | 0.011 | 0.010 |
| Mean Shimmer | : | 0.08 | 0.08 |
| Mean HNR | : | 20.48 | 21.73 |


## CONCLUSION

Voices can be objectively analysed using acoustic parameters like mean pitch, jitter, shimmer and harmonic to noise ratio. A large database yields more reliable normative parameters. Institutions should develop their own standard protocol for selection of subjects, recording of voices and their analysis.

## LIMITATIONS

1. In our study, Voices of children and elderly were not included.
2. The voice samples belong to a population of a restricted area.
3. The voice recording system is specific for our study. It indeed has been different at different establishments. And the results have been varied too. Hence our method can not be universal for use at all the clinics.

## FUTURE PROSPECTS

1. These normative values can be used as benchmark for comparision with parameters of abnormal voices.
2. Using the same methodology we can try to find acoustic parameters of abnormal voices and correlate these parameters with the pathological conditions.
3. The acoustic analysis tool can be used as a yardstick for prediction of dysphonic voices and as a pre-diagnostic tool for early lesions presenting with change in voice.

Master_Chart

| Male | | | | | | Female | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **S.No.** | **File No.** | **mean pitch** | **jitter (ddp)** | **shimmer (dda)** | **HNR Mean** | **S.No.** | **File No.** | **Mean pitch** | **Jitter (ddp)** | **Shimmer (dda)** | **HNR Mean** |
| 1 | 1 | 157.078 | 0.00288 | 0.04642 | 23.856 | 1 | 4 | 260.312 | 0.00472 | 0.04763 | 21.35 |
| 2 | 2 | 218.621 | 0.00436 | 0.13164 | 15.865 | 2 | 6 | 211.109 | 0.01865 | 0.11527 | 18.711 |
| 3 | 3 | 260.215 | 0.00433 | 0.03522 | 21.443 | 3 | 7 | 99.859 | 0.00908 | 0.08382 | 17.286 |
| 4 | 5 | 174.133 | 0.0087 | 0.05129 | 23.422 | 4 | 8 | 216.162 | 0.00749 | 0.1298 | 14.908 |
| 5 | 10 | 204.832 | 0.00944 | 0.0786 | 18.633 | 5 | 9 | 201.103 | 0.00548 | 0.06053 | 24.334 |
| 6 | 11 | 120.6 | 0.00752 | 0.07794 | 16.039 | 6 | 12 | 239.582 | 0.01112 | 0.06795 | 20.554 |
| 7 | 13 | 244.112 | 0.0184 | 0.04202 | 20.611 | 7 | 16 | 108.656 | 0.00673 | 0.09002 | 15.405 |
| 8 | 14 | 132.706 | 0.01685 | 0.17023 | 13.623 | 8 | 17 | 204.157 | 0.00714 | 0.04502 | 26.468 |
| 9 | 15 | 121.736 | 0.00627 | 0.15262 | 14.111 | 9 | 19 | 252.728 | 0.00584 | 0.03522 | 24.686 |
| 10 | 18 | 232.879 | 0.01302 | 0.09566 | 18.451 | 10 | 21 | 111.41 | 0.0096 | 0.03047 | 24.667 |
| 11 | 20 | 209.402 | 0.00848 | 0.04976 | 24.146 | 11 | 23 | 100.391 | 0.00634 | 0.04557 | 18.794 |
| 12 | 22 | 261.694 | 0.00511 | 0.03794 | 25.668 | 12 | 24 | 129.985 | 0.00537 | 0.13476 | 17.007 |
| 13 | 26 | 197.439 | 0.01027 | 0.03603 | 22.141 | 13 | 25 | 114.876 | 0.00473 | 0.05022 | 22.435 |
| 14 | 27 | 215.1 | 0.01287 | 0.15228 | 16.81 | 14 | 29 | 235.959 | 0.00551 | 0.02482 | 26.409 |
| 15 | 28 | 106.493 | 0.00941 | 0.35361 | 7.147 | 15 | 32 | 122.431 | 0.00952 | 0.11156 | 9.957 |
| 16 | 30 | 127.28 | 0.00465 | 0.02816 | 24.45 | 16 | 37 | 263.25 | 0.00569 | 0.0818 | 19.312 |
| 17 | 31 | 127.664 | 0.00738 | 0.0335 | 18.853 | 17 | 38 | 187.941 | 0.00912 | 0.14576 | 12.438 |
| 18 | 33 | 107.204 | 0.01052 | 0.06759 | 23.066 | 18 | 39 | 253.81 | 0.00426 | 0.04685 | 22.189 |
| 19 | 34 | 107.509 | 0.00657 | 0.05316 | 21.374 | 19 | 40 | 131.186 | 0.01035 | 0.08791 | 11.545 |
| 20 | 35 | 107.764 | 0.00922 | 0.04687 | 23.205 | 20 | 41 | 229.5 | 0.00408 | 0.06081 | 17.791 |
| 21 | 36 | 107.821 | 0.01053 | 0.04286 | 22.264 | 21 | 46 | 211.396 | 0.07211 | 0.26901 | 2.17 |
| 22 | 42 | 108.944 | 0.01011 | 0.07096 | 23.161 | 22 | 47 | 465.445 | 0.12455 | 0.67366 | 0.719 |
| 23 | 43 | 109.55 | 0.00749 | 0.07948 | 21.473 | 23 | 51 | 238.939 | 0.00934 | 0.02388 | 27.765 |
| 24 | 44 | 109.295 | 0.02172 | 0.04131 | 17.305 | 24 | 54 | 220.877 | 0.02411 | 0.07989 | 22.745 |
| 25 | 45 | 109.413 | 0.00826 | 0.05169 | 18.354 | 25 | 59 | 273.414 | 0.02172 | 0.17286 | 16.655 |
| 26 | 48 | 124.815 | 0.0037 | 0.03883 | 25.788 | 26 | 64 | 236.607 | 0.00886 | 0.0572 | 21.621 |
| 27 | 49 | 111.123 | 0.00738 | 0.13897 | 14.412 | 27 | 65 | 243.695 | 0.01129 | 0.08858 | 18.191 |
| 28 | 50 | 111.326 | 0.00612 | 0.0906 | 20.511 | 28 | 66 | 201.636 | 0.0147 | 0.07202 | 18.229 |
| 29 | 52 | 126.836 | 0.00348 | 0.03216 | 28.711 | 29 | 67 | 219.9 | 0.01339 | 0.18926 | 13.77 |
| 30 | 53 | 130.735 | 0.00723 | 0.06131 | 23.826 | 30 | 71 | 282.078 | 0.00893 | 0.05435 | 22.555 |
| 31 | 55 | 166.235 | 0.01089 | 0.03434 | 23.588 | 31 | 72 | 253.919 | 0.01363 | 0.12013 | 18.001 |
| 32 | 56 | 269.663 | 0.00498 | 0.03934 | 30.359 | 32 | 74 | 186.653 | 0.00613 | 0.04852 | 24.284 |
| 33 | 57 | 136.366 | 0.00486 | 0.02587 | 28.317 | 33 | 75 | 242.402 | 0.00872 | 0.06949 | 21.227 |
| 34 | 58 | 137.076 | 0.00703 | 0.02712 | 26.937 | 34 | 76 | 249.621 | 0.01714 | 0.08018 | 21.179 |
| 35 | 60 | 121.526 | 0.01207 | 0.22026 | 11.967 | 35 | 80 | 220.521 | 0.00444 | 0.03936 | 25.865 |
| 36 | 61 | 135.547 | 0.01216 | 0.16122 | 13.176 | 36 | 81 | 248.795 | 0.00739 | 0.0541 | 23.096 |
| 37 | 62 | 226.574 | 0.01142 | 0.07489 | 22.965 | 37 | 84 | 215.958 | 0.01672 | 0.11893 | 16.274 |
| 38 | 63 | 195.069 | 0.01587 | 0.13331 | 20.386 | 38 | 85 | 232.602 | 0.00683 | 0.07558 | 19.544 |
| 39 | 68 | 169.826 | 0.03224 | 0.19306 | 14.211 | 39 | 89 | 208.383 | 0.00596 | 0.09458 | 20.582 |
| 40 | 69 | 114.389 | 0.01059 | 0.15656 | 18.099 | 40 | 98 | 239.726 | 0.00728 | 0.13154 | 15.579 |
| 41 | 70 | 114.525 | 0.00368 | 0.07927 | 19.821 | 41 | 99 | 229.75 | 0.01448 | 0.10075 | 19.574 |
| 42 | 73 | 127.056 | 0.00991 | 0.07725 | 22.548 | 42 | 100 | 237.759 | 0.00934 | 0.08649 | 19.361 |
| 43 | 78 | 156.68 | 0.01819 | 0.0489 | 19.655 | 43 | 102 | 218.365 | 0.00853 | 0.05982 | 21.356 |
| 44 | 79 | 136.216 | 0.006 | 0.066 | 21.791 | 44 | 103 | 229.983 | 0.02142 | 0.17407 | 15.586 |
| 45 | 83 | 112.375 | 0.00579 | 0.06912 | 22.339 | 45 | 104 | 227.828 | 0.00615 | 0.07506 | 21.366 |

Master_Chart

| Male | | | | | | Female | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean | S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 46 | 86 | 114.525 | 0.00368 | 0.07927 | 19.821 | 46 | 106 | 253.443 | 0.0042 | 0.06882 | 21.421 |
| 47 | 87 | 115.353 | 0.00526 | 0.06003 | 23.017 | 47 | 107 | 233.929 | 0.00894 | 0.10731 | 17.454 |
| 48 | 88 | 118.849 | 0.00578 | 0.0783 | 22.224 | 48 | 108 | 256.564 | 0.00933 | 0.10491 | 19.136 |
| 49 | 90 | 119.855 | 0.00762 | 0.10327 | 21.55 | 49 | 109 | 245.768 | 0.01019 | 0.12033 | 17.32 |
| 50 | 91 | 101.021 | 0.00924 | 0.32064 | 12.833 | 50 | 110 | 233.695 | 0.01109 | 0.11358 | 20.401 |
| 51 | 92 | 109.876 | 0.00516 | 0.05791 | 22.727 | 51 | 111 | 235.238 | 0.01933 | 0.15769 | 17.686 |
| 52 | 93 | 120.747 | 0.01043 | 0.04354 | 20.624 | 52 | 112 | 176.07 | 0.01173 | 0.14942 | 16.562 |
| 53 | 94 | 123.292 | 0.00783 | 0.04185 | 24.532 | 53 | 114 | 253.427 | 0.01491 | 0.08892 | 19.128 |
| 54 | 95 | 119.886 | 0.01698 | 0.12373 | 17.762 | 54 | 116 | 234.802 | 0.01857 | 0.15601 | 13.829 |
| 55 | 96 | 123.29 | 0.00568 | 0.06046 | 20.219 | 55 | 117 | 229.134 | 0.03471 | 0.23718 | 10.864 |
| 56 | 129 | 122.333 | 0.01969 | 0.08564 | 21.039 | 56 | 118 | 243.905 | 0.00835 | 0.05187 | 25.846 |
| 57 | 131 | 111.123 | 0.00738 | 0.13897 | 14.412 | 57 | 119 | 224.152 | 0.01057 | 0.06362 | 21.738 |
| 58 | 132 | 98.714 | 0.02851 | 0.45302 | 8.299 | 58 | 120 | 279.426 | 0.00559 | 0.06016 | 23.448 |
| 59 | 133 | 136.201 | 0.00972 | 0.14774 | 16.365 | 59 | 121 | 278.849 | 0.00545 | 0.05958 | 23.504 |
| 60 | 134 | 133.14 | 0.00465 | 0.1707 | 17.806 | 60 | 122 | 216.075 | 0.02667 | 0.19303 | 15.817 |
| 61 | 135 | 122.776 | 0.00879 | 0.10605 | 16.079 | 61 | 123 | 223.064 | 0.01382 | 0.11912 | 17.658 |
| 62 | 136 | 156.457 | 0.0049 | 0.02802 | 25.598 | 62 | 124 | 251.166 | 0.00994 | 0.06412 | 23.795 |
| 63 | 137 | 129.048 | 0.00887 | 0.12561 | 17.358 | 63 | 125 | 213.491 | 0.01121 | 0.11847 | 18.581 |
| 64 | 138 | 142.723 | 0.01792 | 0.05515 | 20.029 | 64 | 126 | 252.853 | 0.02141 | 0.14982 | 16.73 |
| 65 | 139 | 130.554 | 0.00637 | 0.02742 | 25.143 | 65 | 127 | 249.901 | 0.00661 | 0.03253 | 28.504 |
| 66 | 140 | 153.082 | 0.00645 | 0.02186 | 27.112 | 66 | 128 | 247.542 | 0.01313 | 0.06732 | 24.712 |
| 67 | 141 | 141.577 | 0.01326 | 0.06869 | 18.764 | 67 | 130 | 253.642 | 0.01256 | 0.11754 | 23.026 |
| 68 | 142 | 135.554 | 0.01023 | 0.0318 | 27.399 | 68 | 143 | 174.186 | 0.01157 | 0.05624 | 20.317 |
| 69 | 150 | 162.364 | 0.01255 | 0.08133 | 17.921 | 69 | 144 | 180.82 | 0.00516 | 0.03602 | 25.36 |
| 70 | 151 | 124.744 | 0.00708 | 0.04925 | 23.284 | 70 | 145 | 220.067 | 0.01252 | 0.07767 | 17.759 |
| 71 | 152 | 139.488 | 0.00653 | 0.04241 | 25.245 | 71 | 146 | 232.266 | 0.01421 | 0.08053 | 17.72 |
| 72 | 155 | 130.669 | 0.00629 | 0.03128 | 26.867 | 72 | 147 | 250.525 | 0.0101 | 0.06203 | 20.268 |
| 73 | 156 | 132.005 | 0.00739 | 0.03037 | 25.032 | 73 | 148 | 224.296 | 0.01325 | 0.07157 | 22.222 |
| 74 | 157 | 155.799 | 0.00481 | 0.02432 | 25.185 | 74 | 149 | 237.171 | 0.00687 | 0.04347 | 23.449 |
| 75 | 158 | 114.217 | 0.04112 | 0.05159 | 20.688 | 75 | 153 | 251.459 | 0.00701 | 0.03676 | 27.893 |
| 76 | 159 | 130.98 | 0.00506 | 0.01984 | 24.375 | 76 | 154 | 229.166 | 0.01252 | 0.04697 | 20.31 |
| 77 | 160 | 111.326 | 0.00612 | 0.0906 | 20.511 | 77 | 163 | 242.376 | 0.00479 | 0.02928 | 25.69 |
| 78 | 161 | 135.561 | 0.00805 | 0.04792 | 21.552 | 78 | 165 | 245.69 | 0.00479 | 0.02586 | 26.585 |
| 79 | 162 | 143.091 | 0.00552 | 0.06772 | 21.577 | 79 | 166 | 230.088 | 0.00802 | 0.0701 | 19.453 |
| 80 | 167 | 139.054 | 0.00579 | 0.03126 | 22.911 | 80 | 169 | 244.572 | 0.00757 | 0.05752 | 26.204 |
| 81 | 168 | 134.322 | 0.00441 | 0.04142 | 26.205 | 81 | 170 | 245.508 | 0.01654 | 0.04591 | 26.715 |
| 82 | 174 | 140.184 | 0.00664 | 0.11396 | 19.076 | 82 | 171 | 201.826 | 0.00857 | 0.04806 | 20.639 |
| 83 | 175 | 142.108 | 0.00352 | 0.03422 | 22.403 | 83 | 172 | 230.043 | 0.00758 | 0.03701 | 27.536 |
| 84 | 176 | 120.404 | 0.00577 | 0.03706 | 26.094 | 84 | 173 | 248.82 | 0.00569 | 0.03235 | 28.685 |
| 85 | 179 | 141.377 | 0.00425 | 0.03872 | 26.924 | 85 | 177 | 256.777 | 0.00751 | 0.03147 | 26.123 |
| 86 | 180 | 171.591 | 0.01054 | 0.06971 | 22.146 | 86 | 178 | 225.767 | 0.00762 | 0.03493 | 21.723 |
| 87 | 181 | 175.601 | 0.00807 | 0.05369 | 24.552 | 87 | 182 | 238.716 | 0.00991 | 0.05852 | 26.247 |
| 88 | 193 | 148.513 | 0.0032 | 0.08042 | 20.736 | 88 | 183 | 226.709 | 0.00253 | 0.03803 | 26.699 |
| 89 | 195 | 129.784 | 0.00727 | 0.08399 | 22.268 | 89 | 184 | 308.28 | 0.0098 | 0.09578 | 21.155 |
| 90 | 196 | 129.985 | 0.00537 | 0.13476 | 17.007 | 90 | 185 | 200.928 | 0.00938 | 0.11107 | 17.288 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
| 91 | 197 | 129.561 | 0.02999 | 0.42094 | 7.873 |
| 92 | 198 | 130.091 | 0.00706 | 0.04578 | 22.114 |
| 93 | 199 | 130.176 | 0.02482 | 0.11239 | 15.252 |
| 94 | 200 | 130.347 | 0.00574 | 0.10142 | 19.761 |
| 95 | 214 | 131.3 | 0.01218 | 0.05873 | 19.602 |
| 96 | 217 | 125.868 | 0.00648 | 0.08862 | 18.894 |
| 97 | 218 | 134.134 | 0.00621 | 0.08104 | 17.192 |
| 98 | 219 | 129.077 | 0.00402 | 0.03385 | 21.514 |
| 99 | 220 | 76.432 | 0.00247 | 0.1624 | 19.674 |
| 100 | 221 | 100.2 | 0.03581 | 0.31255 | 6.811 |
| 101 | 222 | 129.428 | 0.01246 | 0.081 | 18.37 |
| 102 | 223 | 122.096 | 0.00657 | 0.09215 | 22.648 |
| 103 | 227 | 183.356 | 0.00261 | 0.01632 | 33.129 |
| 104 | 228 | 180.957 | 0.01072 | 0.04759 | 24.759 |
| 105 | 229 | 125.844 | 0.04033 | 0.04402 | 15.435 |
| 106 | 230 | 126.975 | 0.00834 | 0.10669 | 20.37 |
| 107 | 231 | 130.11 | 0.01409 | 0.24831 | 12.189 |
| 108 | 236 | 133.533 | 0.01045 | 0.08424 | 14.785 |
| 109 | 248 | 142.363 | 0.00442 | 0.05249 | 24.722 |
| 110 | 249 | 122.333 | 0.01969 | 0.08564 | 21.039 |
| 111 | 251 | 223.107 | 0.00706 | 0.05002 | 23.416 |
| 112 | 252 | 138.669 | 0.00666 | 0.06305 | 17.974 |
| 113 | 253 | 121.921 | 0.00681 | 0.05859 | 25.094 |
| 114 | 254 | 145.887 | 0.00822 | 0.06852 | 24.894 |
| 115 | 255 | 139.331 | 0.00257 | 0.02734 | 30.614 |
| 116 | 256 | 124.716 | 0.00649 | 0.03441 | 23.882 |
| 117 | 259 | 187.046 | 0.00731 | 0.06432 | 21.713 |
| 118 | 260 | 145.468 | 0.00798 | 0.05356 | 20.614 |
| 119 | 261 | 102.266 | 0.00568 | 0.02648 | 25.78 |
| 120 | 266 | 121.083 | 0.0102 | 0.06668 | 22.394 |
| 121 | 267 | 151.508 | 0.01866 | 0.07942 | 22.317 |
| 122 | 269 | 147.164 | 0.01193 | 0.07038 | 20.998 |
| 123 | 277 | 130.415 | 0.00642 | 0.05479 | 23.458 |
| 124 | 278 | 117.185 | 0.02043 | 0.08135 | 20.547 |
| 125 | 279 | 99.989 | 0.0112 | 0.06686 | 23.983 |
| 126 | 280 | 114.82 | 0.00831 | 0.20379 | 15.052 |
| 127 | 281 | 155.489 | 0.00692 | 0.11836 | 18.653 |
| 128 | 282 | 129.417 | 0.03172 | 0.06346 | 16.877 |
| 129 | 283 | 125.866 | 0.00626 | 0.05968 | 25.67 |
| 130 | 284 | 131.104 | 0.01168 | 0.24685 | 12.671 |
| 131 | 285 | 188.351 | 0.01031 | 0.0748 | 24.502 |
| 132 | 286 | 120.311 | 0.01061 | 0.07347 | 19.83 |
| 133 | 287 | 122.165 | 0.01819 | 0.07142 | 20.484 |
| 134 | 288 | 108.259 | 0.01078 | 0.09734 | 20.612 |
| 135 | 289 | 94.704 | 0.00844 | 0.13755 | 12.339 |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 91 | 186 | 205.764 | 0.00496 | 0.03682 | 25.215 |
| 92 | 187 | 254.174 | 0.00445 | 0.02479 | 32.016 |
| 93 | 188 | 232.605 | 0.0069 | 0.02796 | 24.832 |
| 94 | 189 | 233.98 | 0.00833 | 0.05996 | 22.738 |
| 95 | 190 | 263.166 | 0.01195 | 0.10076 | 19.541 |
| 96 | 191 | 257.425 | 0.00459 | 0.04144 | 25.503 |
| 97 | 192 | 256.571 | 0.00805 | 0.09014 | 20.759 |
| 98 | 194 | 120.587 | 0.00229 | 0.03489 | 24.9 |
| 99 | 201 | 224.551 | 0.00529 | 0.03419 | 25.725 |
| 100 | 202 | 205.433 | 0.00461 | 0.02926 | 30.524 |
| 101 | 203 | 249.434 | 0.00371 | 0.0328 | 32.368 |
| 102 | 204 | 85.694 | 0.04017 | 0.1176 | 17.071 |
| 103 | 205 | 235.843 | 0.01044 | 0.02671 | 30.315 |
| 104 | 206 | 232.277 | 0.00856 | 0.06492 | 25.349 |
| 105 | 207 | 235.297 | 0.00365 | 0.02516 | 28.936 |
| 106 | 208 | 231.013 | 0.0062 | 0.03452 | 27.18 |
| 107 | 209 | 240.741 | 0.00618 | 0.03684 | 26.005 |
| 108 | 210 | 250.265 | 0.00536 | 0.03259 | 31.658 |
| 109 | 211 | 281.718 | 0.00466 | 0.03724 | 24.341 |
| 110 | 212 | 276.805 | 0.00432 | 0.03725 | 26.822 |
| 111 | 213 | 323.304 | 0.00444 | 0.01799 | 27.333 |
| 112 | 215 | 257.687 | 0.00448 | 0.02406 | 29.643 |
| 113 | 216 | 255.419 | 0.00581 | 0.02896 | 28.176 |
| 114 | 224 | 258.438 | 0.02336 | 0.13981 | 19.175 |
| 115 | 225 | 244.456 | 0.01797 | 0.08232 | 19.716 |
| 116 | 226 | 248.632 | 0.00612 | 0.0619 | 22.801 |
| 117 | 232 | 261.604 | 0.01442 | 0.05169 | 22.406 |
| 118 | 234 | 278.194 | 0.00983 | 0.08695 | 22.486 |
| 119 | 235 | 239.296 | 0.01075 | 0.18166 | 12.043 |
| 120 | 237 | 220.144 | 0.01188 | 0.07656 | 22.902 |
| 121 | 238 | 233.475 | 0.00982 | 0.07195 | 21.329 |
| 122 | 239 | 241.956 | 0.00744 | 0.03656 | 23.746 |
| 123 | 240 | 241.389 | 0.01352 | 0.06586 | 24.356 |
| 124 | 241 | 242.081 | 0.00775 | 0.06297 | 23.835 |
| 125 | 242 | 231.958 | 0.00753 | 0.04763 | 25.618 |
| 126 | 243 | 251.749 | 0.02449 | 0.13373 | 18.279 |
| 127 | 244 | 221.775 | 0.00983 | 0.1057 | 20.406 |
| 128 | 245 | 243.641 | 0.0091 | 0.05649 | 24.561 |
| 129 | 247 | 256.725 | 0.01561 | 0.05096 | 26.42 |
| 130 | 250 | 214.844 | 0.00582 | 0.03832 | 24.777 |
| 131 | 257 | 260.935 | 0.01472 | 0.07594 | 21.606 |
| 132 | 258 | 147.765 | 0.02151 | 0.06548 | 19.23 |
| 133 | 262 | 220.713 | 0.0157 | 0.14751 | 17.223 |
| 134 | 263 | 223.936 | 0.00445 | 0.05794 | 22.072 |
| 135 | 264 | 219.622 | 0.0097 | 0.09523 | 16.966 |

| Male | | | | | | | Female | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean | | S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 136 | 290 | 135.327 | 0.01169 | 0.04991 | 18.174 | | 136 | 265 | 137.955 | 0.00699 | 0.05955 | 23.415 |
| 137 | 292 | 132.91 | 0.01475 | 0.08976 | 15.983 | | 137 | 268 | 199.971 | 0.01133 | 0.27768 | 15.501 |
| 138 | 293 | 128.934 | 0.00565 | 0.10702 | 15.885 | | 138 | 270 | 253.001 | 0.02248 | 0.12309 | 19.554 |
| 139 | 294 | 132.573 | 0.00455 | 0.11062 | 17.614 | | 139 | 271 | 245.551 | 0.01195 | 0.05733 | 23.706 |
| 140 | 295 | 148.991 | 0.00732 | 0.10965 | 19.941 | | 140 | 272 | 243.49 | 0.0058 | 0.06279 | 22.715 |
| 141 | 296 | 106.493 | 0.00941 | 0.35361 | 7.147 | | 141 | 273 | 250.036 | 0.01378 | 0.05946 | 23.267 |
| 142 | 311 | 141.772 | 0.00507 | 0.05177 | 26.416 | | 142 | 274 | 204.706 | 0.03846 | 0.29915 | 8.685 |
| 143 | 312 | 131.649 | 0.00629 | 0.04622 | 21.604 | | 143 | 275 | 232.896 | 0.00858 | 0.065 | 22.232 |
| 144 | 313 | 148.08 | 0.00942 | 0.04545 | 19.175 | | 144 | 276 | 244.283 | 0.01087 | 0.13886 | 18.063 |
| 145 | 314 | 165.673 | 0.01549 | 0.13609 | 17.021 | | 145 | 291 | 140.031 | 0.00372 | 0.06584 | 17.028 |
| 146 | 315 | 128.253 | 0.00602 | 0.05033 | 21.55 | | 146 | 297 | 237.179 | 0.00589 | 0.06231 | 19.984 |
| 147 | 316 | 136.83 | 0.00415 | 0.0418 | 26.194 | | 147 | 298 | 234.995 | 0.00411 | 0.0695 | 22.379 |
| 148 | 317 | 122.267 | 0.01157 | 0.04098 | 21.326 | | 148 | 299 | 172.212 | 0.00699 | 0.07949 | 19.675 |
| 149 | 318 | 114.256 | 0.01165 | 0.09195 | 18.988 | | 149 | 300 | 245.665 | 0.00582 | 0.0865 | 20.011 |
| 150 | 319 | 181.672 | 0.01962 | 0.07457 | 22.483 | | 150 | 301 | 213.105 | 0.00554 | 0.04502 | 26.09 |
| 151 | 320 | 142.404 | 0.00718 | 0.04058 | 26.555 | | 151 | 302 | 199.582 | 0.0125 | 0.07904 | 16.611 |
| 152 | 321 | 143.293 | 0.00424 | 0.03236 | 28.917 | | 152 | 303 | 250.263 | 0.01583 | 0.0974 | 20.001 |
| 153 | 322 | 140.568 | 0.00849 | 0.02797 | 25.986 | | 153 | 305 | 226.138 | 0.01215 | 0.06823 | 21.747 |
| 154 | 323 | 122.677 | 0.01512 | 0.12253 | 18.053 | | 154 | 306 | 196.218 | 0.01349 | 0.1027 | 20.377 |
| 155 | 324 | 113.925 | 0.0077 | 0.07422 | 20.765 | | 155 | 307 | 227.435 | 0.00497 | 0.05281 | 22.716 |
| 156 | 334 | 113.347 | 0.00968 | 0.04667 | 23.817 | | 156 | 308 | 248.522 | 0.01402 | 0.08492 | 20.854 |
| 157 | 335 | 111.835 | 0.0275 | 0.08491 | 18.607 | | 157 | 309 | 203.886 | 0.00818 | 0.04324 | 21.567 |
| 158 | 336 | 120.089 | 0.00842 | 0.03743 | 23.469 | | 158 | 310 | 250.2 | 0.01553 | 0.09654 | 19.857 |
| 159 | 337 | 121.304 | 0.00552 | 0.03401 | 23.722 | | 159 | 325 | 244.862 | 0.00634 | 0.08378 | 19.114 |
| 160 | 338 | 134.592 | 0.00655 | 0.0455 | 25.756 | | 160 | 326 | 263.988 | 0.0074 | 0.05116 | 23.141 |
| 161 | 339 | 148.063 | 0.00452 | 0.02755 | 27.947 | | 161 | 327 | 130.347 | 0.00574 | 0.10142 | 19.761 |
| 162 | 340 | 120.118 | 0.01085 | 0.06468 | 21.956 | | 162 | 328 | 269.27 | 0.01384 | 0.12659 | 17.659 |
| 163 | 341 | 190.297 | 0.00661 | 0.04793 | 26.841 | | 163 | 329 | 264.327 | 0.00983 | 0.06296 | 20.586 |
| 164 | 342 | 128.722 | 0.00541 | 0.03701 | 28.226 | | 164 | 330 | 238.933 | 0.00952 | 0.0832 | 18.758 |
| 165 | 343 | 135.288 | 0.1537 | 0.22815 | 11.373 | | 165 | 331 | 268.679 | 0.00702 | 0.05711 | 22.332 |
| 166 | 344 | 121.237 | 0.01158 | 0.16373 | 14.721 | | 166 | 332 | 212.365 | 0.0083 | 0.05307 | 20.083 |
| 167 | 352 | 153.735 | 0.00565 | 0.07731 | 20.919 | | 167 | 333 | 259.263 | 0.00631 | 0.0322 | 23.294 |
| 168 | 353 | 101.54 | 0.00626 | 0.03796 | 23.136 | | 168 | 345 | 270.002 | 0.0069 | 0.03938 | 24.46 |
| 169 | 354 | 163.744 | 0.00662 | 0.03665 | 22.89 | | 169 | 346 | 257.226 | 0.00762 | 0.03935 | 27.275 |
| 170 | 356 | 112.337 | 0.00439 | 0.03251 | 26.189 | | 170 | 347 | 256.643 | 0.00877 | 0.05354 | 23.545 |
| 171 | 357 | 132.094 | 0.01219 | 0.04247 | 21.99 | | 171 | 348 | 244.957 | 0.01174 | 0.05251 | 21.424 |
| 172 | 358 | 157.382 | 0.02219 | 0.05317 | 20.291 | | 172 | 349 | 256.268 | 0.00707 | 0.0476 | 23.041 |
| 173 | 360 | 155.514 | 0.00406 | 0.04228 | 23.66 | | 173 | 350 | 267.892 | 0.0049 | 0.03063 | 26.832 |
| 174 | 364 | 157.714 | 0.00554 | 0.06466 | 21.746 | | 174 | 351 | 252.241 | 0.01002 | 0.06354 | 19.49 |
| 175 | 396 | 104.391 | 0.00614 | 0.03411 | 22.053 | | 175 | 361 | 239.653 | 0.00456 | 0.03066 | 24.658 |
| 176 | 397 | 114.947 | 0.0247 | 0.05857 | 17.563 | | 176 | 362 | 238.936 | 0.00893 | 0.07083 | 23.101 |
| 177 | 398 | 125.886 | 0.06306 | 0.26455 | 10.196 | | 177 | 363 | 258.826 | 0.00521 | 0.0309 | 27.821 |
| 178 | 399 | 117.877 | 0.01594 | 0.07564 | 22.952 | | 178 | 365 | 250.443 | 0.00704 | 0.0663 | 22.496 |
| 179 | 400 | 124.764 | 0.00346 | 0.01659 | 25.872 | | 179 | 366 | 237.689 | 0.00837 | 0.06029 | 21.314 |
| 180 | 401 | 190.297 | 0.00661 | 0.04793 | 26.841 | | 180 | 367 | 223.769 | 0.013 | 0.03061 | 25.276 |

**Male**

| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
|---|---|---|---|---|---|
| 181 | 429 | 159.842 | 0.00871 | 0.1455 | 14.371 |
| 182 | 430 | 157.714 | 0.00554 | 0.06466 | 21.746 |
| 183 | 431 | 85.519 | 0.01627 | 0.06891 | 14.345 |
| 184 | 433 | 132.806 | 0.00908 | 0.07243 | 18.072 |
| 185 | 442 | 154.941 | 0.01173 | 0.05193 | 21.385 |
| 186 | 443 | 104.944 | 0.00791 | 0.04145 | 24.626 |
| 187 | 444 | 142.342 | 0.00678 | 0.0518 | 20.384 |
| 188 | 446 | 211.914 | 0.01804 | 0.0653 | 21.695 |
| 189 | 447 | 118.988 | 0.00601 | 0.04728 | 24.053 |
| 190 | 448 | 124.744 | 0.00708 | 0.04925 | 23.284 |
| 191 | 450 | 132.911 | 0.01442 | 0.17265 | 12.843 |
| 192 | 453 | 130.357 | 0.00572 | 0.04016 | 26.19 |
| 193 | 454 | 127.991 | 0.01791 | 0.14865 | 14.272 |
| 194 | 455 | 121.665 | 0.0088 | 0.06571 | 22.79 |
| 195 | 465 | 219.919 | 0.00416 | 0.03741 | 24.066 |
| 196 | 466 | 219.54 | 0.00523 | 0.0508 | 26.241 |
| 197 | 478 | 104.968 | 0.00937 | 0.06577 | 21.21 |
| 198 | 479 | 122.334 | 0.01332 | 0.07785 | 19.008 |
| 199 | 487 | 135.632 | 0.01067 | 0.04411 | 23.016 |
| 200 | 488 | 103.09 | 0.00918 | 0.05744 | 19.254 |
| 201 | 489 | 133.533 | 0.01045 | 0.08424 | 14.785 |
| 202 | 490 | 223.59 | 0.00807 | 0.04602 | 23.017 |
| 203 | 491 | 130.091 | 0.00706 | 0.04578 | 22.114 |
| 204 | 492 | 153.936 | 0.00645 | 0.05319 | 21.287 |
| 205 | 493 | 142.347 | 0.01787 | 0.03145 | 21.841 |
| 206 | 494 | 135.456 | 0.0219 | 0.04425 | 21.716 |
| 207 | 495 | 108.944 | 0.01011 | 0.07096 | 23.161 |
| 208 | 496 | 116.35 | 0.00682 | 0.06312 | 24.726 |
| 209 | 497 | 134.129 | 0.00529 | 0.06026 | 22.348 |
| 210 | 498 | 159.221 | 0.00684 | 0.05247 | 20.822 |
| 211 | 499 | 139.975 | 0.00259 | 0.03493 | 21.723 |
| 212 | 500 | 123.536 | 0.00623 | 0.11517 | 17.571 |
| 213 | 512 | 145.655 | 0.01149 | 0.04377 | 19.781 |
| 214 | 513 | 133.668 | 0.01396 | 0.03537 | 23.559 |
| 215 | 514 | 148.365 | 0.01336 | 0.0436 | 17.848 |
| 216 | 534 | 136.573 | 0.00535 | 0.02679 | 26.18 |
| 217 | 535 | 144.926 | 0.01086 | 0.05012 | 22.379 |
| 218 | 536 | 126.093 | 0.00552 | 0.0293 | 25.43 |
| 219 | 537 | 138.128 | 0.00527 | 0.02588 | 28.931 |
| 220 | 538 | 110.741 | 0.14634 | 0.32438 | 7.715 |
| 221 | 539 | 114.152 | 0.00823 | 0.0379 | 17.851 |
| 222 | 540 | 134.757 | 0.01283 | 0.03574 | 23.832 |
| 223 | 541 | 119.043 | 0.00458 | 0.03476 | 25.192 |
| 224 | 542 | 120.194 | 0.01621 | 0.07123 | 19.898 |
| 225 | 543 | 145.485 | 0.00789 | 0.05425 | 20.797 |

**Female**

| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
|---|---|---|---|---|---|
| 181 | 368 | 219.919 | 0.00416 | 0.03741 | 24.066 |
| 182 | 369 | 218.509 | 0.01028 | 0.05833 | 21.662 |
| 183 | 370 | 232.938 | 0.00678 | 0.03694 | 26.398 |
| 184 | 371 | 231.271 | 0.01988 | 0.03486 | 24.304 |
| 185 | 372 | 216.67 | 0.00683 | 0.03739 | 25.395 |
| 186 | 373 | 252.354 | 0.01157 | 0.08201 | 19.313 |
| 187 | 374 | 227.036 | 0.0054 | 0.02911 | 28.83 |
| 188 | 375 | 208.521 | 0.00839 | 0.07625 | 20.91 |
| 189 | 376 | 226.02 | 0.00727 | 0.04603 | 24.597 |
| 190 | 377 | 241.011 | 0.00506 | 0.01883 | 31.942 |
| 191 | 378 | 237.651 | 0.00555 | 0.02673 | 27.647 |
| 192 | 379 | 226.908 | 0.00983 | 0.04082 | 23.622 |
| 193 | 380 | 228.862 | 0.01046 | 0.04955 | 21.406 |
| 194 | 381 | 233.602 | 0.00557 | 0.05678 | 24.789 |
| 195 | 382 | 231.067 | 0.00345 | 0.03193 | 29.034 |
| 196 | 383 | 282.86 | 0.00528 | 0.02723 | 27.746 |
| 197 | 384 | 272.252 | 0.0045 | 0.02613 | 27.536 |
| 198 | 385 | 259.861 | 0.00563 | 0.03048 | 25.934 |
| 199 | 386 | 261.964 | 0.0034 | 0.02011 | 28.999 |
| 200 | 387 | 259.709 | 0.01492 | 0.07677 | 18.914 |
| 201 | 388 | 256.072 | 0.01433 | 0.03698 | 19.939 |
| 202 | 390 | 256.475 | 0.01064 | 0.08349 | 20.275 |
| 203 | 391 | 253.027 | 0.00349 | 0.04517 | 23.535 |
| 204 | 392 | 251.501 | 0.01226 | 0.05909 | 20.613 |
| 205 | 393 | 232.79 | 0.00678 | 0.03409 | 29.261 |
| 206 | 394 | 214.711 | 0.00478 | 0.03283 | 24.989 |
| 207 | 402 | 195.069 | 0.01587 | 0.13331 | 20.386 |
| 208 | 403 | 194.625 | 0.01316 | 0.09448 | 19.261 |
| 209 | 404 | 196.218 | 0.01349 | 0.1027 | 20.377 |
| 210 | 405 | 176.07 | 0.01173 | 0.14942 | 16.562 |
| 211 | 406 | 197.439 | 0.01027 | 0.03603 | 22.141 |
| 212 | 407 | 199.582 | 0.0125 | 0.07904 | 16.611 |
| 213 | 408 | 200.928 | 0.00938 | 0.11107 | 17.288 |
| 214 | 409 | 201.103 | 0.00548 | 0.06053 | 24.334 |
| 215 | 410 | 201.636 | 0.0147 | 0.07202 | 18.229 |
| 216 | 411 | 201.826 | 0.00857 | 0.04806 | 20.639 |
| 217 | 412 | 204.157 | 0.00714 | 0.04502 | 26.468 |
| 218 | 413 | 204.015 | 0.00738 | 0.02946 | 25.884 |
| 219 | 414 | 203.886 | 0.00818 | 0.04324 | 21.567 |
| 220 | 415 | 204.706 | 0.03846 | 0.29915 | 8.685 |
| 221 | 416 | 204.832 | 0.00944 | 0.0786 | 18.633 |
| 222 | 417 | 205.433 | 0.00461 | 0.02926 | 30.524 |
| 223 | 418 | 205.764 | 0.00496 | 0.03682 | 25.215 |
| 224 | 419 | 206.554 | 0.0062 | 0.03603 | 26.76 |
| 225 | 420 | 207.474 | 0.00676 | 0.03961 | 28.119 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
| 226 | 544 | 136.07 | 0.00721 | 0.10443 | 15.663 |
| 227 | 545 | 168.056 | 0.00634 | 0.02052 | 24.496 |
| 228 | 546 | 128.032 | 0.00859 | 0.04274 | 20.123 |
| 229 | 547 | 144.362 | 0.00533 | 0.08039 | 19.848 |
| 230 | 548 | 157.449 | 0.01734 | 0.04237 | 26.787 |
| 231 | 549 | 140.869 | 0.00387 | 0.0221 | 29.348 |
| 232 | 550 | 137.227 | 0.00722 | 0.04617 | 25.011 |
| 233 | 551 | 108.93 | 0.00897 | 0.07199 | 21.091 |
| 234 | 552 | 129.611 | 0.00349 | 0.02046 | 29.336 |
| 235 | 553 | 162.704 | 0.00478 | 0.02662 | 29.942 |
| 236 | 554 | 137.924 | 0.00527 | 0.0402 | 28.34 |
| 237 | 555 | 120.22 | 0.0063 | 0.0152 | 23.081 |
| 238 | 556 | 133.482 | 0.00893 | 0.03678 | 21.261 |
| 239 | 603 | 132.58 | 0.00932 | 0.04982 | 24.201 |
| 240 | 604 | 108.33 | 0.01601 | 0.20862 | 16.129 |
| 241 | 605 | 120.302 | 0.00795 | 0.12346 | 17.285 |
| 242 | 606 | 132.511 | 0.00651 | 0.11646 | 18.36 |
| 243 | 607 | 102.277 | 0.0064 | 0.11993 | 17.242 |
| 244 | 608 | 111.344 | 0.02282 | 0.0922 | 16.397 |
| 245 | 609 | 216.101 | 0.02325 | 0.20093 | 13.052 |
| 246 | 611 | 134.021 | 0.01654 | 0.06417 | 23.822 |
| 247 | 612 | 106.858 | 0.01643 | 0.18073 | 16.06 |
| 248 | 616 | 129.183 | 0.00911 | 0.08201 | 18.792 |
| 249 | 617 | 134.997 | 0.01074 | 0.18237 | 16.644 |
| 250 | 618 | 126.459 | 0.01025 | 0.15292 | 17.593 |
| 251 | 619 | 145.206 | 0.00986 | 0.08012 | 22.667 |
| 252 | 629 | 123.695 | 0.00798 | 0.17501 | 18.424 |
| 253 | 630 | 116.781 | 0.01081 | 0.27086 | 11.864 |
| 254 | 631 | 125.01 | 0.07795 | 0.2054 | 9.822 |
| 255 | 632 | 146.461 | 0.01559 | 0.25356 | 12.221 |
| 256 | 633 | 131.145 | 0.00552 | 0.03735 | 27.74 |
| 257 | 635 | 125.563 | 0.00481 | 0.05262 | 25.957 |
| 258 | 636 | 131.324 | 0.00712 | 0.2209 | 15.431 |
| 259 | 638 | 131.3 | 0.01218 | 0.05873 | 19.602 |
| 260 | 644 | 169.419 | 0.00445 | 0.04465 | 23.713 |
| 261 | 645 | 113.677 | 0.0085 | 0.082 | 16.418 |
| 262 | 647 | 129.561 | 0.02999 | 0.42094 | 7.873 |
| 263 | 648 | 124.962 | 0.00516 | 0.0474 | 21.033 |
| 264 | 649 | 121.637 | 0.0112 | 0.05251 | 18.256 |
| 265 | 650 | 173.463 | 0.0062 | 0.05834 | 25.253 |
| 266 | 651 | 163.38 | 0.00645 | 0.08473 | 20.533 |
| 267 | 652 | 129.784 | 0.00727 | 0.08399 | 22.268 |
| 268 | 653 | 140.687 | 0.01998 | 0.08716 | 19.584 |
| 269 | 654 | 140.273 | 0.01098 | 0.12193 | 19.314 |
| 270 | 661 | 105.067 | 0.00652 | 0.0499 | 15.858 |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 226 | 421 | 207.908 | 0.0331 | 0.21644 | 13.936 |
| 227 | 422 | 208.052 | 0.00927 | 0.05765 | 21.461 |
| 228 | 423 | 208.34 | 0.01554 | 0.20188 | 15.715 |
| 229 | 424 | 208.409 | 0.01179 | 0.06393 | 18.091 |
| 230 | 425 | 208.772 | 0.01327 | 0.10058 | 18.357 |
| 231 | 426 | 208.383 | 0.00596 | 0.09458 | 20.582 |
| 232 | 427 | 249.086 | 0.01308 | 0.13469 | 20.155 |
| 233 | 428 | 279.484 | 0.00474 | 0.01893 | 32.948 |
| 234 | 432 | 218.365 | 0.00853 | 0.05982 | 21.356 |
| 235 | 434 | 233.774 | 0.01066 | 0.0893 | 20.371 |
| 236 | 436 | 232.552 | 0.00659 | 0.05982 | 20.539 |
| 237 | 437 | 253.201 | 0.00614 | 0.03564 | 25.27 |
| 238 | 438 | 284.204 | 0.00939 | 0.08534 | 18.751 |
| 239 | 439 | 244.221 | 0.00757 | 0.12184 | 15.844 |
| 240 | 440 | 253.809 | 0.01412 | 0.10476 | 19.173 |
| 241 | 441 | 252.893 | 0.00649 | 0.05139 | 26.512 |
| 242 | 445 | 289.967 | 0.00941 | 0.07061 | 24.132 |
| 243 | 449 | 231.896 | 0.01611 | 0.08113 | 18.333 |
| 244 | 451 | 234.062 | 0.01038 | 0.14156 | 16.365 |
| 245 | 452 | 229.086 | 0.00856 | 0.0352 | 24.341 |
| 246 | 456 | 219.084 | 0.00756 | 0.05385 | 23.949 |
| 247 | 457 | 218.621 | 0.00436 | 0.13164 | 15.865 |
| 248 | 458 | 218.701 | 0.00492 | 0.0283 | 27.977 |
| 249 | 459 | 218.447 | 0.00561 | 0.07626 | 22.204 |
| 250 | 460 | 218.509 | 0.01028 | 0.05833 | 21.662 |
| 251 | 461 | 220.331 | 0.00842 | 0.06271 | 22.261 |
| 252 | 462 | 219.622 | 0.0097 | 0.09523 | 16.966 |
| 253 | 463 | 220.067 | 0.01252 | 0.07767 | 17.759 |
| 254 | 464 | 219.9 | 0.01339 | 0.18926 | 13.77 |
| 255 | 467 | 220.144 | 0.01188 | 0.07656 | 22.902 |
| 256 | 468 | 220.3 | 0.00471 | 0.03737 | 24.972 |
| 257 | 469 | 220.412 | 0.00871 | 0.07499 | 19.93 |
| 258 | 470 | 220.616 | 0.01499 | 0.13958 | 16.391 |
| 259 | 471 | 220.521 | 0.00444 | 0.03936 | 25.865 |
| 260 | 472 | 220.55 | 0.0037 | 0.0259 | 26.127 |
| 261 | 473 | 220.877 | 0.02411 | 0.07989 | 22.745 |
| 262 | 474 | 220.713 | 0.0157 | 0.14751 | 17.223 |
| 263 | 475 | 220.684 | 0.00766 | 0.08896 | 19.154 |
| 264 | 476 | 221.37 | 0.00696 | 0.05374 | 22.963 |
| 265 | 480 | 247.676 | 0.00481 | 0.11046 | 18.06 |
| 266 | 481 | 225.743 | 0.01531 | 0.11517 | 17.571 |
| 267 | 482 | 226.223 | 0.01211 | 0.04853 | 24.413 |
| 268 | 483 | 230.182 | 0.01815 | 0.10893 | 19.061 |
| 269 | 484 | 237.127 | 0.01011 | 0.04431 | 22.086 |
| 270 | 485 | 225.356 | 0.00786 | 0.05247 | 20.822 |

| Male | | | | | | Female | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean | S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 271 | 662 | 119.427 | 0.00586 | 0.04907 | 21.62 | 271 | 486 | 234.037 | 0.00915 | 0.06725 | 18.948 |
| 272 | 663 | 103.934 | 0.00782 | 0.15189 | 16.219 | 272 | 501 | 220.616 | 0.01499 | 0.13958 | 16.391 |
| 273 | 664 | 119.694 | 0.00938 | 0.1104 | 21.423 | 273 | 502 | 240.132 | 0.00802 | 0.05496 | 24.397 |
| 274 | 665 | 105.059 | 0.00641 | 0.07146 | 19.637 | 274 | 503 | 223.084 | 0.00555 | 0.04273 | 25.171 |
| 275 | 678 | 151.789 | 0.0072 | 0.04104 | 23.24 | 275 | 504 | 227.631 | 0.00469 | 0.02353 | 27.835 |
| 276 | 679 | 144.471 | 0.00494 | 0.0304 | 25.302 | 276 | 505 | 248.112 | 0.01061 | 0.02489 | 22.639 |
| 277 | 680 | 138.99 | 0.00463 | 0.01974 | 25.836 | 277 | 506 | 232.982 | 0.00461 | 0.02693 | 27.024 |
| 278 | 681 | 152.831 | 0.00609 | 0.03988 | 22.198 | 278 | 507 | 231.768 | 0.00401 | 0.02608 | 28.8 |
| 279 | 682 | 125.403 | 0.00497 | 0.03605 | 25.914 | 279 | 508 | 241.027 | 0.00405 | 0.02313 | 27.845 |
| 280 | 683 | 128.68 | 0.0111 | 0.05544 | 23.128 | 280 | 510 | 249.506 | 0.00564 | 0.03194 | 25.505 |
| 281 | 684 | 106.866 | 0.00375 | 0.0289 | 25.576 | 281 | 511 | 254.409 | 0.01337 | 0.04501 | 19.728 |
| 282 | 685 | 138.664 | 0.00583 | 0.02301 | 26.93 | 282 | 515 | 273.096 | 0.01526 | 0.06591 | 19.273 |
| 283 | 686 | 108.401 | 0.00632 | 0.04674 | 20.653 | 283 | 516 | 255.526 | 0.00618 | 0.02089 | 27.983 |
| 284 | 687 | 124.024 | 0.00359 | 0.03615 | 24.253 | 284 | 517 | 221.662 | 0.01077 | 0.04905 | 24.611 |
| 285 | 688 | 135.961 | 0.00822 | 0.06801 | 18.58 | 285 | 518 | 274.002 | 0.0088 | 0.04442 | 21.933 |
| 286 | 704 | 127.793 | 0.00948 | 0.11617 | 14.682 | 286 | 519 | 228.042 | 0.00546 | 0.01996 | 33.809 |
| 287 | 705 | 121.369 | 0.0102 | 0.03657 | 20.849 | 287 | 520 | 253.372 | 0.00602 | 0.03316 | 25.711 |
| 288 | 706 | 112.673 | 0.00961 | 0.04026 | 22.041 | 288 | 521 | 274.79 | 0.00319 | 0.02241 | 31.276 |
| 289 | 707 | 109.413 | 0.00826 | 0.05169 | 18.354 | 289 | 522 | 244.941 | 0.00769 | 0.03013 | 26.656 |
| 290 | 708 | 121.961 | 0.01457 | 0.18801 | 12.152 | 290 | 523 | 221.809 | 0.00863 | 0.04036 | 24.337 |
| 291 | 709 | 121.993 | 0.00672 | 0.04523 | 18.634 | 291 | 524 | 250.135 | 0.00458 | 0.03956 | 26.847 |
| 292 | 710 | 125.379 | 0.00376 | 0.05003 | 18.682 | 292 | 525 | 253.187 | 0.0113 | 0.03864 | 25.015 |
| 293 | 711 | 130.652 | 0.00404 | 0.10077 | 15.207 | 293 | 526 | 277.773 | 0.00706 | 0.03641 | 29.752 |
| 294 | 712 | 127.425 | 0.00789 | 0.0773 | 15.907 | 294 | 527 | 224.274 | 0.00937 | 0.02734 | 25.784 |
| 295 | 715 | 131.66 | 0.02489 | 0.32858 | 10.374 | 295 | 528 | 278.22 | 0.00509 | 0.01829 | 31.579 |
| 296 | 716 | 119.172 | 0.02433 | 0.3354 | 11.156 | 296 | 529 | 225.103 | 0.00667 | 0.04209 | 26.891 |
| 297 | 717 | 137.323 | 0.00619 | 0.0859 | 21.207 | 297 | 530 | 241.584 | 0.00386 | 0.02208 | 29.193 |
| 298 | 718 | 124.254 | 0.02401 | 0.10194 | 15.206 | 298 | 531 | 234.029 | 0.00623 | 0.02459 | 28.522 |
| 299 | 732 | 107.155 | 0.01433 | 0.20684 | 15.701 | 299 | 532 | 265.91 | 0.00445 | 0.02789 | 32.232 |
| 300 | 733 | 116.081 | 0.02357 | 0.12967 | 16.113 | 300 | 533 | 252.952 | 0.01124 | 0.0476 | 27.12 |
| 301 | 734 | 130.874 | 0.0077 | 0.15558 | 17.946 | 301 | 557 | 232.785 | 0.01998 | 0.21314 | 12.911 |
| 302 | 735 | 130.176 | 0.02482 | 0.11239 | 15.252 | 302 | 558 | 233.138 | 0.00471 | 0.04665 | 22.496 |
| 303 | 736 | 130.198 | 0.00937 | 0.06839 | 21.362 | 303 | 559 | 232.896 | 0.00858 | 0.065 | 22.232 |
| 304 | 737 | 130.364 | 0.02723 | 0.06781 | 18.931 | 304 | 560 | 232.79 | 0.00678 | 0.03409 | 29.261 |
| 305 | 738 | 142.512 | 0.02423 | 0.05712 | 21.342 | 305 | 561 | 233.475 | 0.00982 | 0.07195 | 21.329 |
| 306 | 740 | 136.933 | 0.01563 | 0.06503 | 21.426 | 306 | 562 | 233.929 | 0.00894 | 0.10731 | 17.454 |
| 307 | 741 | 131.987 | 0.01215 | 0.04207 | 24.335 | 307 | 563 | 233.695 | 0.01109 | 0.11358 | 20.401 |
| 308 | 742 | 128.495 | 0.01003 | 0.06103 | 24.671 | 308 | 564 | 233.98 | 0.00833 | 0.05996 | 22.738 |
| 309 | 743 | 125.053 | 0.03601 | 0.12401 | 16.748 | 309 | 565 | 233.602 | 0.00557 | 0.05678 | 24.789 |
| 310 | 753 | 107.204 | 0.01052 | 0.06759 | 23.066 | 310 | 566 | 234.029 | 0.00623 | 0.02459 | 28.522 |
| 311 | 754 | 152.028 | 0.01822 | 0.23696 | 15.234 | 311 | 567 | 233.774 | 0.01066 | 0.0893 | 20.371 |
| 312 | 764 | 137.339 | 0.01193 | 0.03272 | 25.234 | 312 | 568 | 234.062 | 0.01038 | 0.14156 | 16.365 |
| 313 | 765 | 139.445 | 0.00605 | 0.09834 | 20.22 | 313 | 569 | 234.037 | 0.00915 | 0.06725 | 18.948 |
| 314 | 766 | 161.481 | 0.00677 | 0.05397 | 25.581 | 314 | 570 | 234.802 | 0.01857 | 0.15601 | 13.829 |
| 315 | 767 | 149.99 | 0.00431 | 0.04313 | 23.775 | 315 | 571 | 233.998 | 0.00503 | 0.05438 | 23.467 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
| 316 | 768 | 164.438 | 0.02887 | 0.11255 | 18.41 |
| 317 | 769 | 139.69 | 0.00609 | 0.28481 | 14.756 |
| 318 | 770 | 146.975 | 0.01368 | 0.19782 | 13.209 |
| 319 | 771 | 138.677 | 0.00528 | 0.08755 | 20.731 |
| 320 | 772 | 139.026 | 0.02763 | 0.22156 | 13.527 |
| 321 | 773 | 145.385 | 0.00795 | 0.04039 | 22.897 |
| 322 | 774 | 125.579 | 0.01259 | 0.05387 | 21.344 |
| 323 | 775 | 152.548 | 0.00797 | 0.0856 | 20.629 |
| 324 | 776 | 125.007 | 0.01014 | 0.16589 | 15.632 |
| 325 | 777 | 140.66 | 0.00557 | 0.09493 | 17.613 |
| 326 | 780 | 122.886 | 0.01358 | 0.05311 | 22.549 |
| 327 | 781 | 141.73 | 0.01647 | 0.19188 | 12.962 |
| 328 | 782 | 153.735 | 0.00565 | 0.07731 | 20.919 |
| 329 | 783 | 142.815 | 0.00416 | 0.10032 | 20.036 |
| 330 | 784 | 115.872 | 0.02273 | 0.05337 | 22.67 |
| 331 | 798 | 161.254 | 0.00798 | 0.01181 | 27.829 |
| 332 | 799 | 123.781 | 0.02297 | 0.09399 | 17.724 |
| 333 | 800 | 165.899 | 0.00645 | 0.0695 | 22.929 |
| 334 | 803 | 155.777 | 0.01729 | 0.05828 | 21.323 |
| 335 | 804 | 107.821 | 0.01053 | 0.04286 | 22.264 |
| 336 | 805 | 153.27 | 0.0054 | 0.03261 | 22.628 |
| 337 | 807 | 140.447 | 0.00503 | 0.03803 | 23.706 |
| 338 | 809 | 143.106 | 0.00731 | 0.032 | 26.804 |
| 339 | 811 | 111.192 | 0.00687 | 0.02676 | 24.29 |
| 340 | 812 | 140.496 | 0.01121 | 0.06091 | 15.751 |
| 341 | 813 | 160.766 | 0.00445 | 0.04851 | 21.157 |
| 342 | 814 | 115.034 | 0.00402 | 0.02292 | 25.042 |
| 343 | 815 | 131.739 | 0.00477 | 0.04018 | 21.686 |
| 344 | 816 | 122.809 | 0.01607 | 0.12656 | 18.365 |
| 345 | 818 | 134.367 | 0.00439 | 0.02177 | 29.792 |
| 346 | 819 | 134.424 | 0.00574 | 0.02089 | 28.5 |
| 347 | 820 | 112.238 | 0.00862 | 0.05951 | 20.14 |
| 348 | 821 | 129.227 | 0.00639 | 0.06279 | 21.716 |
| 349 | 822 | 138.845 | 0.00575 | 0.03232 | 23.607 |
| 350 | 823 | 107.509 | 0.00657 | 0.05316 | 21.374 |
| 351 | 824 | 118.899 | 0.00809 | 0.03295 | 23.936 |
| 352 | 825 | 144.077 | 0.0105 | 0.06215 | 23.883 |
| 353 | 826 | 145.715 | 0.0219 | 0.09934 | 14.657 |
| 354 | 827 | 171.301 | 0.00489 | 0.0645 | 21.775 |
| 355 | 828 | 140.498 | 0.00781 | 0.06066 | 19.544 |
| 356 | 829 | 136.935 | 0.0105 | 0.07361 | 19.93 |
| 357 | 830 | 165.119 | 0.00814 | 0.04731 | 22.206 |
| 358 | 831 | 130.559 | 0.00807 | 0.02472 | 19.492 |
| 359 | 849 | 119.353 | 0.06893 | 0.07851 | 14.661 |
| 360 | 853 | 102.705 | 0.00887 | 0.05576 | 23.7 |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 316 | 572 | 235.959 | 0.00551 | 0.02482 | 26.409 |
| 317 | 573 | 234.995 | 0.00411 | 0.0695 | 22.379 |
| 318 | 574 | 235.297 | 0.00365 | 0.02516 | 28.936 |
| 319 | 575 | 235.238 | 0.01933 | 0.15769 | 17.686 |
| 320 | 576 | 235.653 | 0.00901 | 0.06107 | 21.858 |
| 321 | 577 | 232.266 | 0.01421 | 0.08053 | 17.72 |
| 322 | 578 | 235.843 | 0.01044 | 0.02671 | 30.315 |
| 323 | 579 | 208.521 | 0.00839 | 0.07625 | 20.91 |
| 324 | 580 | 236.439 | 0.01614 | 0.08532 | 20.862 |
| 325 | 581 | 236.013 | 0.00818 | 0.06712 | 19.689 |
| 326 | 582 | 236.204 | 0.0085 | 0.04748 | 20.969 |
| 327 | 583 | 236.607 | 0.00886 | 0.0572 | 21.621 |
| 328 | 584 | 236.527 | 0.0072 | 0.06768 | 19.583 |
| 329 | 585 | 236.772 | 0.00856 | 0.06652 | 20.16 |
| 330 | 586 | 236.799 | 0.01784 | 0.11792 | 17.055 |
| 331 | 587 | 237.127 | 0.01011 | 0.04431 | 22.086 |
| 332 | 588 | 237.179 | 0.00589 | 0.06231 | 19.984 |
| 333 | 589 | 224.296 | 0.01325 | 0.07157 | 22.222 |
| 334 | 590 | 237.255 | 0.01091 | 0.06445 | 21.575 |
| 335 | 591 | 237.689 | 0.00837 | 0.06029 | 21.314 |
| 336 | 592 | 237.651 | 0.00555 | 0.02673 | 27.647 |
| 337 | 593 | 237.503 | 0.00781 | 0.07634 | 21.184 |
| 338 | 594 | 237.171 | 0.00687 | 0.04347 | 23.449 |
| 339 | 595 | 237.469 | 0.00551 | 0.03305 | 27.409 |
| 340 | 596 | 237.484 | 0.01711 | 0.17928 | 14.59 |
| 341 | 597 | 238.295 | 0.00774 | 0.07072 | 21.48 |
| 342 | 598 | 237.953 | 0.00306 | 0.02307 | 30.561 |
| 343 | 599 | 237.759 | 0.00934 | 0.08649 | 19.361 |
| 344 | 600 | 239.296 | 0.01075 | 0.18166 | 12.043 |
| 345 | 601 | 238.716 | 0.00991 | 0.05852 | 26.247 |
| 346 | 602 | 208.052 | 0.00927 | 0.05765 | 21.461 |
| 347 | 610 | 258.161 | 0.06427 | 0.26769 | 8.136 |
| 348 | 613 | 208.34 | 0.01554 | 0.20188 | 15.715 |
| 349 | 614 | 225.982 | 0.0056 | 0.05627 | 25.03 |
| 350 | 615 | 220.3 | 0.00471 | 0.03737 | 24.972 |
| 351 | 620 | 229.09 | 0.00742 | 0.19445 | 13.998 |
| 352 | 621 | 237.484 | 0.01711 | 0.17928 | 14.59 |
| 353 | 622 | 236.799 | 0.01784 | 0.11792 | 17.055 |
| 354 | 623 | 255.281 | 0.01468 | 0.07654 | 20.963 |
| 355 | 624 | 240.566 | 0.01155 | 0.07103 | 23.773 |
| 356 | 625 | 248.892 | 0.00948 | 0.07768 | 19.633 |
| 357 | 626 | 207.908 | 0.0331 | 0.21644 | 13.936 |
| 358 | 627 | 242.359 | 0.02872 | 0.26261 | 9.923 |
| 359 | 628 | 208.951 | 0.01407 | 0.13871 | 17.18 |
| 360 | 634 | 242.359 | 0.02872 | 0.26261 | 9.923 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
| 361 | 854 | 124.107 | 0.01181 | 0.0365 | 19.492 |
| 362 | 855 | 160.257 | 0.01859 | 0.06947 | 22.352 |
| 363 | 856 | 143.17 | 0.01159 | 0.09038 | 17.687 |
| 364 | 858 | 137.735 | 0.00554 | 0.05199 | 24.81 |
| 365 | 860 | 135.206 | 0.00363 | 0.0427 | 27.875 |
| 366 | 861 | 137.026 | 0.00327 | 0.03699 | 29.953 |
| 367 | 865 | 101.27 | 0.00699 | 0.04066 | 21.469 |
| 368 | 866 | 97.405 | 0.01523 | 0.05395 | 17.341 |
| 369 | 867 | 141.931 | 0.00754 | 0.04544 | 23.191 |
| 370 | 868 | 121.01 | 0.02201 | 0.06371 | 16.995 |
| 371 | 869 | 122.085 | 0.00928 | 0.05672 | 21.729 |
| 372 | 878 | 162.023 | 0.01601 | 0.16919 | 18.478 |
| 373 | 880 | 119.085 | 0.00562 | 0.29854 | 4.335 |
| 374 | 884 | 165.541 | 0.00516 | 0.05345 | 23.449 |
| 375 | 891 | 148.974 | 0.02398 | 0.04115 | 20.821 |
| 376 | 892 | 99.568 | 0.02453 | 0.06084 | 21.08 |
| 377 | 893 | 152.902 | 0.00716 | 0.0374 | 25.345 |
| 378 | 894 | 135.921 | 0.04395 | 0.16719 | 16.689 |
| 379 | 895 | 119.467 | 0.01091 | 0.04303 | 24.31 |
| 380 | 896 | 127.037 | 0.00925 | 0.04646 | 25.375 |
| 381 | 897 | 113.733 | 0.01665 | 0.06944 | 21.708 |
| 382 | 898 | 103.286 | 0.00488 | 0.04169 | 24.155 |
| 383 | 899 | 96.684 | 0.01695 | 0.05864 | 17.951 |
| 384 | 901 | 120.537 | 0.00509 | 0.07826 | 21.937 |
| 385 | 902 | 149.553 | 0.00416 | 0.05471 | 24.715 |
| 386 | 903 | 116.662 | 0.02475 | 0.09958 | 19.257 |
| 387 | 904 | 149.2 | 0.0108 | 0.05899 | 17.556 |
| 388 | 908 | 278.194 | 0.00983 | 0.08695 | 22.486 |
| 389 | 910 | 144.307 | 0.00667 | 0.07504 | 20.575 |
| 390 | 911 | 118.405 | 0.0081 | 0.06119 | 16.483 |
| 391 | 912 | 132.873 | 0.00808 | 0.07188 | 21.619 |
| 392 | 913 | 133.621 | 0.00407 | 0.02899 | 27.847 |
| 393 | 914 | 134.902 | 0.00809 | 0.02958 | 23.024 |
| 394 | 933 | 122.163 | 0.007 | 0.03645 | 23.221 |
| 395 | 934 | 158.941 | 0.01082 | 0.04068 | 21.175 |
| 396 | 935 | 130.939 | 0.00608 | 0.07622 | 22.658 |
| 397 | 936 | 187.776 | 0.00444 | 0.02668 | 27.539 |
| 398 | 937 | 125.465 | 0.00805 | 0.05072 | 23.215 |
| 399 | 938 | 138.432 | 0.00788 | 0.04766 | 20.38 |
| 400 | 939 | 122.02 | 0.00583 | 0.12131 | 19.255 |
| 401 | 940 | 124.124 | 0.00697 | 0.03639 | 26.112 |
| 402 | 941 | 123.557 | 0.0073 | 0.05388 | 21.553 |
| 403 | 942 | 104.157 | 0.01053 | 0.32621 | 10.611 |
| 404 | 945 | 118.507 | 0.0272 | - | 0.711 |
| 405 | 946 | 109.389 | 0.00728 | 0.19431 | 5.608 |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 361 | 637 | 276.829 | 0.01011 | 0.11675 | 16.276 |
| 362 | 639 | 236.772 | 0.00856 | 0.06652 | 20.16 |
| 363 | 640 | 255.297 | 0.01471 | 0.09977 | 19.601 |
| 364 | 641 | 233.999 | 0.02421 | 0.08218 | 21.059 |
| 365 | 642 | 243.946 | 0.00775 | 0.14827 | 16.975 |
| 366 | 643 | 275.912 | 0.00945 | 0.07559 | 21.217 |
| 367 | 646 | 244.283 | 0.01087 | 0.13886 | 18.063 |
| 368 | 655 | 276.717 | 0.00956 | 0.08417 | 20.201 |
| 369 | 656 | 309.601 | 0.00568 | 0.05043 | 24.376 |
| 370 | 657 | 264.325 | 0.01455 | 0.06048 | 20.433 |
| 371 | 658 | 238.295 | 0.00774 | 0.07072 | 21.48 |
| 372 | 659 | 237.503 | 0.00781 | 0.07634 | 21.184 |
| 373 | 660 | 233.134 | 0.00468 | 0.04976 | 23.248 |
| 374 | 667 | 217.325 | 0.00466 | 0.07325 | 20.152 |
| 375 | 668 | 262.398 | 0.01405 | 0.10345 | 18.363 |
| 376 | 669 | 257.022 | 0.02826 | 0.15108 | 18.599 |
| 377 | 670 | 254.843 | 0.02788 | 0.14932 | 16.691 |
| 378 | 671 | 227.481 | 0.02309 | 0.21028 | 14.66 |
| 379 | 672 | 206.554 | 0.0062 | 0.03603 | 26.76 |
| 380 | 673 | 231.559 | 0.01552 | 0.09457 | 20.076 |
| 381 | 674 | 240.744 | 0.00617 | 0.05589 | 23.054 |
| 382 | 675 | 236.013 | 0.00818 | 0.06712 | 19.689 |
| 383 | 676 | 248.775 | 0.00578 | 0.04632 | 24.581 |
| 384 | 677 | 241.702 | 0.00889 | 0.13168 | 17.177 |
| 385 | 689 | 221.561 | 0.01666 | 0.0524 | 23.99 |
| 386 | 690 | 230.561 | 0.00718 | 0.04686 | 22.393 |
| 387 | 691 | 218.701 | 0.00492 | 0.0283 | 27.977 |
| 388 | 692 | 240.795 | 0.00535 | 0.04071 | 24.985 |
| 389 | 693 | 226.773 | 0.00339 | 0.02158 | 28.224 |
| 390 | 694 | 264.165 | 0.01282 | 0.04908 | 22.836 |
| 391 | 695 | 187.039 | 0.00411 | 0.04775 | 26.458 |
| 392 | 696 | 242.525 | 0.00421 | 0.01823 | 29.607 |
| 393 | 697 | 210.604 | 0.00684 | 0.04354 | 27.351 |
| 394 | 698 | 270.966 | 0.00695 | 0.0432 | 24.845 |
| 395 | 699 | 224.696 | 0.01774 | 0.03549 | 20.346 |
| 396 | 700 | 236.204 | 0.0085 | 0.04748 | 20.969 |
| 397 | 701 | 212.164 | 0.01134 | 0.0697 | 19.198 |
| 398 | 702 | 230.933 | 0.00923 | 0.04277 | 24.894 |
| 399 | 703 | 211.359 | 0.00517 | 0.0381 | 23.221 |
| 400 | 713 | 250.349 | 0.00296 | 0.02335 | 23.643 |
| 401 | 714 | 241.41 | 0.00474 | 0.02444 | 24.94 |
| 402 | 720 | 245.1 | 0.00963 | 0.09985 | 20.2 |
| 403 | 721 | 258.214 | 0.02155 | 0.20994 | 13.166 |
| 404 | 722 | 248.824 | 0.01721 | 0.11484 | 19.529 |
| 405 | 723 | 251.088 | 0.01593 | 0.07715 | 22.488 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
| 406 | 947 | 105.849 | 0.00687 | 0.1098 | 15.696 |
| 407 | 948 | 217.97 | 0.01492 | 0.07451 | 12.691 |
| 408 | 949 | 116.359 | 0.00664 | 0.06561 | 11.35 |
| 409 | 950 | 114.317 | 0.00456 | 0.211 | 7.042 |
| 410 | 951 | 119.353 | 0.06893 | 0.07851 | 14.661 |
| 411 | 952 | 126.707 | 0.00827 | 0.04211 | 25.971 |
| 412 | 953 | 109.295 | 0.02172 | 0.04131 | 17.305 |
| 413 | 954 | 106.783 | 0.01234 | 0.05051 | 21.541 |
| 414 | 955 | 141.357 | 0.02485 | 0.11695 | 18.497 |
| 415 | 956 | 147.833 | 0.02658 | 0.08129 | 20.137 |
| 416 | 957 | 129.367 | 0.00584 | 0.04238 | 23.82 |
| 417 | 958 | 158.477 | 0.01068 | 0.04678 | 22.366 |
| 418 | 959 | 115.568 | 0.007 | 0.05026 | 22.463 |
| 419 | 960 | 123.589 | 0.01002 | 0.05853 | 21.693 |
| 420 | 961 | 110.123 | 0.01637 | 0.08693 | 18.178 |
| 421 | 962 | 109.55 | 0.00749 | 0.07948 | 21.473 |
| 422 | 963 | 114.389 | 0.01059 | 0.15656 | 18.099 |
| 423 | 964 | 107.764 | 0.00922 | 0.04687 | 23.205 |
| 424 | 965 | 191.236 | 0.00537 | 0.1106 | 15.768 |
| 425 | 966 | 109.973 | 0.00745 | 0.10838 | 12.164 |
| 426 | 967 | 109.973 | 0.00745 | 0.10838 | 12.164 |
| 427 | 968 | 125.485 | 0.01478 | 0.22183 | 10.522 |
| 428 | 969 | 199.063 | 0.02259 | 0.34317 | 3.264 |
| 429 | 970 | 122.814 | 0.00331 | 0.09053 | 10.016 |
| 430 | 971 | 222.985 | 0.00768 | 0.14648 | 13.624 |
| 431 | 974 | 199.971 | 0.01133 | 0.27768 | 15.501 |
| 432 | 975 | 128.375 | 0.01869 | 0.05936 | 18.921 |
| 433 | 985 | 116.472 | 0.01535 | 0.05391 | 21.666 |
| 434 | 986 | 127.057 | 0.01217 | 0.1015 | 22.208 |
| 435 | 987 | 119.098 | 0.01119 | 0.05956 | 19.294 |
| 436 | 988 | 115.028 | 0.00708 | 0.10248 | 15.348 |
| 437 | 998 | 141.323 | 0.00941 | 0.04144 | 26.558 |
| 438 | 999 | 122.55 | 0.00344 | 0.02521 | 24.013 |
| 439 | 359 | 111.836 | 0.00753 | 0.07737 | 21.208 |
| 440 | 77 | 115.872 | 0.02273 | 0.05337 | 22.67 |
| 441 | 82 | 116.662 | 0.02475 | 0.09958 | 19.257 |
| 442 | 97 | 119.855 | 0.00762 | 0.10327 | 21.55 |
| 443 | 101 | 120.089 | 0.00842 | 0.03743 | 23.469 |
| 444 | 113 | 246.54 | 0.03609 | 0.16283 | 15.88 |
| 445 | 115 | 121.369 | 0.0102 | 0.03657 | 20.849 |
| 446 | 164 | 125.866 | 0.00626 | 0.05968 | 25.67 |
| 447 | 233 | 114.027 | 0.01053 | 0.04634 | 23.971 |
| 448 | 246 | 134.902 | 0.00809 | 0.02958 | 23.024 |
| 449 | 304 | 141.73 | 0.01647 | 0.19188 | 12.962 |
| 450 | 355 | 154.941 | 0.01173 | 0.05193 | 21.385 |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 406 | 724 | 253.591 | 0.00978 | 0.06259 | 22.684 |
| 407 | 725 | 255.758 | 0.0232 | 0.0981 | 22.229 |
| 408 | 726 | 256.508 | 0.03743 | 0.18446 | 15.212 |
| 409 | 727 | 243.298 | 0.01089 | 0.0527 | 26.701 |
| 410 | 728 | 247.911 | 0.00729 | 0.03374 | 25.846 |
| 411 | 729 | 259.162 | 0.00779 | 0.08416 | 21.349 |
| 412 | 730 | 272.926 | 0.01171 | 0.0563 | 25.596 |
| 413 | 731 | 284.447 | 0.0166 | 0.15965 | 13.716 |
| 414 | 744 | 220.684 | 0.00766 | 0.08896 | 19.154 |
| 415 | 745 | 208.772 | 0.01327 | 0.10058 | 18.357 |
| 416 | 746 | 255.204 | 0.01438 | 0.05787 | 25.877 |
| 417 | 747 | 227.861 | 0.01713 | 0.17438 | 13.928 |
| 418 | 748 | 252.99 | 0.02104 | 0.12163 | 19.495 |
| 419 | 749 | 223.607 | 0.00782 | 0.09079 | 20.527 |
| 420 | 750 | 230.572 | 0.00497 | 0.04582 | 23.727 |
| 421 | 751 | 246.141 | 0.02061 | 0.23583 | 12.892 |
| 422 | 752 | 257.691 | 0.01307 | 0.13881 | 15.99 |
| 423 | 755 | 259.595 | 0.00616 | 0.05296 | 23.014 |
| 424 | 756 | 245.898 | 0.0074 | 0.07817 | 19.126 |
| 425 | 757 | 258.28 | 0.01083 | 0.16413 | 14.382 |
| 426 | 758 | 245.473 | 0.01708 | 0.15312 | 15.784 |
| 427 | 759 | 254.696 | 0.02373 | 0.12997 | 16.648 |
| 428 | 760 | 244.76 | 0.02619 | 0.13974 | 17.364 |
| 429 | 761 | 246.962 | 0.01264 | 0.07644 | 21.233 |
| 430 | 762 | 233.998 | 0.00503 | 0.05438 | 23.467 |
| 431 | 763 | 232.785 | 0.01998 | 0.21314 | 12.911 |
| 432 | 778 | 264.325 | 0.01455 | 0.06048 | 20.433 |
| 433 | 785 | 240.494 | 0.02046 | 0.14595 | 16.997 |
| 434 | 786 | 230.211 | 0.01292 | 0.13028 | 17.598 |
| 435 | 787 | 240.693 | 0.06261 | 0.26784 | 12.782 |
| 436 | 788 | 240.737 | 0.01437 | 0.12013 | 17.117 |
| 437 | 789 | 256.778 | 0.02448 | 0.17179 | 16.188 |
| 438 | 790 | 239.133 | 0.06283 | 0.28032 | 11.968 |
| 439 | 791 | 258.407 | 0.01897 | 0.11548 | 20.976 |
| 440 | 792 | 246.202 | 0.00915 | 0.0522 | 27.139 |
| 441 | 793 | 272.926 | 0.01171 | 0.0563 | 25.596 |
| 442 | 794 | 273.096 | 0.01526 | 0.06591 | 19.273 |
| 443 | 795 | 273.414 | 0.02172 | 0.17286 | 16.655 |
| 444 | 796 | 274.002 | 0.0088 | 0.04442 | 21.933 |
| 445 | 797 | 274.79 | 0.00319 | 0.02241 | 31.276 |
| 446 | 801 | 251.517 | 0.00591 | 0.04816 | 22.165 |
| 447 | 802 | 267.924 | 0.01087 | 0.08972 | 18.524 |
| 448 | 808 | 220.55 | 0.0037 | 0.0259 | 26.127 |
| 449 | 810 | 244.87 | 0.0073 | 0.06648 | 24.379 |
| 450 | 817 | 289.967 | 0.00941 | 0.07061 | 24.132 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |
| 451 | 395 | 183.356 | 0.00261 | 0.01632 | 33.129 |
| 452 | 435 | 212.527 | 0.01107 | 0.04825 | 19.996 |
| 453 | 719 | 253.427 | 0.01491 | 0.08892 | 19.128 |
| 454 | 739 | 257.687 | 0.00448 | 0.02406 | 29.643 |
| 455 | 806 | 278.194 | 0.00983 | 0.08695 | 22.486 |
| 456 | 845 | 105.849 | 0.00687 | 0.1098 | 15.696 |
| 457 | 890 | 173.717 | 0.01295 | 0.14553 | 14.333 |
| 458 | 246 | 134.902 | 0.00809 | 0.02958 | 23.024 |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 451 | 833 | 147.411 | 0.00635 | 0.16423 | 10.051 |
| 452 | 834 | 204.68 | 0.023 | 0.12954 | 13.156 |
| 453 | 835 | 236.527 | 0.0072 | 0.06768 | 19.583 |
| 454 | 836 | 217.714 | 0.00361 | 0.02417 | 29.448 |
| 455 | 838 | 256.727 | 0.00565 | 0.03209 | 25.379 |
| 456 | 839 | 238.801 | 0.0041 | 0.01742 | 29.708 |
| 457 | 840 | 221.336 | 0.00734 | 0.02234 | 29.187 |
| 458 | 841 | 268.489 | 0.00808 | 0.06296 | 22.542 |
| 459 | 842 | 248.405 | 0.00305 | 0.02669 | 29.192 |
| 460 | 843 | 212.527 | 0.01107 | 0.04825 | 19.996 |
| 461 | 844 | 219.54 | 0.00523 | 0.0508 | 26.241 |
| 462 | 846 | 236.439 | 0.01614 | 0.08532 | 20.862 |
| 463 | 847 | 237.469 | 0.00551 | 0.03305 | 27.409 |
| 464 | 848 | 240.485 | 0.01051 | 0.06672 | 24.829 |
| 465 | 850 | 258.483 | 0.09822 | 0.47 | 2.051 |
| 466 | 851 | 237.953 | 0.00306 | 0.02307 | 30.561 |
| 467 | 852 | 211.538 | 0.00514 | 0.03047 | 25.233 |
| 468 | 857 | 219.084 | 0.00756 | 0.05385 | 23.949 |
| 469 | 859 | 220.331 | 0.00842 | 0.06271 | 22.261 |
| 470 | 862 | 218.447 | 0.00561 | 0.07626 | 22.204 |
| 471 | 863 | 221.37 | 0.00696 | 0.05374 | 22.963 |
| 472 | 864 | 233.138 | 0.00471 | 0.04665 | 22.496 |
| 473 | 870 | 240.83 | 0.00805 | 0.04602 | 22.816 |
| 474 | 871 | 231.668 | 0.00415 | 0.03712 | 23.869 |
| 475 | 872 | 231.287 | 0.00341 | 0.02686 | 28.19 |
| 476 | 873 | 214.957 | 0.00741 | 0.08628 | 19.179 |
| 477 | 874 | 216.334 | 0.0069 | 0.04401 | 25.108 |
| 478 | 875 | 247.034 | 0.00484 | 0.03033 | 26.694 |
| 479 | 876 | 241.393 | 0.0045 | 0.02708 | 29.372 |
| 480 | 877 | 220.412 | 0.00871 | 0.07499 | 19.93 |
| 481 | 879 | 222.906 | 0.00891 | 0.06074 | 21.492 |
| 482 | 881 | 230.338 | 0.00752 | 0.05501 | 20.575 |
| 483 | 882 | 221.443 | 0.01107 | 0.16077 | 15.618 |
| 484 | 883 | 216.39 | 0.00589 | 0.04005 | 27.97 |
| 485 | 885 | 268.828 | 0.02424 | 0.09812 | 17.726 |
| 486 | 886 | 240.025 | 0.00697 | 0.02923 | 26.587 |
| 487 | 887 | 244.912 | 0.00589 | 0.03402 | 25.601 |
| 488 | 888 | 248.25 | 0.00534 | 0.07778 | 20.936 |
| 489 | 889 | 228.042 | 0.00546 | 0.01996 | 33.809 |
| 490 | 900 | 275.912 | 0.00945 | 0.07559 | 21.217 |
| 491 | 905 | 278.22 | 0.00509 | 0.01829 | 31.579 |
| 492 | 906 | 278.285 | 0.00303 | 0.02205 | 29.199 |
| 493 | 907 | 278.175 | 0.01846 | 0.31782 | 1.02 |
| 494 | 909 | 279.426 | 0.00559 | 0.06016 | 23.448 |
| 495 | 915 | 278.285 | 0.00303 | 0.02205 | 29.199 |

| Male | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | mean pitch | jitter (ddp) | shimmer (dda) | HNR Mean |

| Female | | | | | |
|---|---|---|---|---|---|
| S.No. | File No. | Mean pitch | Jitter (ddp) | Shimmer (dda) | HNR Mean |
| 496 | 916 | 261.301 | 0.00715 | 0.04549 | 22.669 |
| 497 | 917 | 271.303 | 0.00284 | 0.02411 | 30.855 |
| 498 | 918 | 232.642 | 0.0128 | 0.09734 | 18.356 |
| 499 | 919 | 285.03 | 0.01163 | 0.074 | 18.997 |
| 500 | 920 | 237.255 | 0.01091 | 0.06445 | 21.575 |
| 501 | 921 | 226.834 | 0.01466 | 0.05366 | 25.831 |
| 502 | 922 | 208.409 | 0.01179 | 0.06393 | 18.091 |
| 503 | 923 | 213.533 | 0.02798 | 0.07971 | 15.838 |
| 504 | 924 | 227.286 | 0.01289 | 0.09811 | 16.391 |
| 505 | 925 | 235.653 | 0.00901 | 0.06107 | 21.858 |
| 506 | 926 | 244.002 | 0.01257 | 0.06829 | 20.315 |
| 507 | 927 | 207.474 | 0.00676 | 0.03961 | 28.119 |
| 508 | 928 | 244.015 | 0.00705 | 0.05215 | 22.22 |
| 509 | 929 | 241.164 | 0.00635 | 0.04129 | 20.023 |
| 510 | 930 | 262.166 | 0.004 | 0.04006 | 25.78 |
| 511 | 931 | 226.66 | 0.00409 | 0.07144 | 22.685 |
| 512 | 932 | 213.183 | 0.00474 | 0.05181 | 24.679 |
| 513 | 943 | 201.942 | 0.005 | 0.12503 | 14.309 |
| 514 | 944 | 303.152 | 0.02445 | 0.2648 | 6.091 |
| 515 | 972 | 210.408 | 0.00885 | 0.19436 | 11.406 |
| 516 | 973 | 259.151 | 0.01763 | 0.24619 | 12.343 |
| 517 | 976 | 221.398 | 0.01202 | 0.04842 | 23.429 |
| 518 | 977 | 223.59 | 0.00807 | 0.04602 | 23.017 |
| 519 | 978 | 231.684 | 0.00466 | 0.03163 | 28.317 |
| 520 | 979 | 194.625 | 0.01316 | 0.09448 | 19.261 |
| 521 | 980 | 216.421 | 0.00767 | 0.06388 | 20.474 |
| 522 | 981 | 174.685 | 0.01458 | 0.15863 | 14.886 |
| 523 | 982 | 204.015 | 0.00738 | 0.02946 | 25.884 |
| 524 | 983 | 242.487 | 0.00477 | 0.02517 | 32.845 |
| 525 | 984 | 268.664 | 0.0262 | 0.05284 | 23.555 |
| 526 | 989 | 281.911 | 0.00556 | 0.03708 | 27.362 |
| 527 | 990 | 192.555 | 0.01839 | 0.22669 | 11.001 |
| 528 | 991 | 262.215 | 0.01405 | 0.07253 | 23.118 |
| 529 | 992 | 250.391 | 0.00784 | 0.0865 | 23.299 |
| 530 | 993 | 227.44 | 0.00598 | 0.04517 | 23.787 |
| 531 | 994 | 257.422 | 0.00446 | 0.06147 | 22.812 |
| 532 | 995 | 244.33 | 0.01329 | 0.07129 | 19.078 |
| 533 | 996 | 294.404 | 0.00682 | 0.0582 | 25.2 |
| 534 | 997 | 247.768 | 0.00854 | 0.08529 | 22.368 |
| 535 | 1000 | 253.074 | 0.01093 | 0.06304 | 17.564 |
| 536 | 979 | 194.625 | 0.01316 | 0.09448 | 19.261 |
| 537 | 993 | 227.44 | 0.00598 | 0.04517 | 23.787 |
| 538 | 982 | 204.015 | 0.00738 | 0.02946 | 25.884 |
| 539 | 928 | 244.015 | 0.00705 | 0.05215 | 22.22 |
| 540 | 994 | 257.422 | 0.00446 | 0.06147 | 22.812 |

| Male | | | | | |
|---|---|---|---|---|---|
| **S.No.** | **File No.** | **mean pitch** | **jitter (ddp)** | **shimmer (dda)** | **HNR Mean** |

| Female | | | | | |
|---|---|---|---|---|---|
| **S.No.** | **File No.** | **Mean pitch** | **Jitter (ddp)** | **Shimmer (dda)** | **HNR Mean** |
| 541 | 980 | 216.421 | 0.00767 | 0.06388 | 20.474 |
| 542 | 885 | 268.828 | 0.02424 | 0.09812 | 17.726 |

**BLDE (DEEMED TO BE UNIVERSITY)**

**Annexure -I**

## PLAGARISM VERIFICATION CERTIFICATE

1. **Name of the Student:** LATHADEVI HASSAN THOTAPPA **Reg No.** 11PHDEN1
2. **Title of the Thesis:** Development of a tool to objectively identify normal human voice.
3. **Department:** ENT
4. **Name of the Guide & Designation:** Dr. S P Guggarigoudar, Professor
5. **Name of the Co Guide & Designation:**……………………………………

**The above thesis was verified for similarity detection. The report is as follows:**

**Software used.** Urkund **Date:** 23-12-2019

**Similarity Index(%):** Two (2%) **Total word Count**……….

**The report is attached for the review by the Student and Guide.**

**The plagiarism report of the above thesis has been reviewed by the undersigned.**

**The similarity index is below accepted norms.**

**The similarity index is above accepted norms, because of following reasons:**

—

**The thesis may be considered for submission to the University. The software report is attached.**

H.T. Lathadevi

| **Signature of the Guide** | **Signature of Co-Guide** | **Signature of Student** |
|---|---|---|
| **Name & Designation** | **Name & Designation** | |

24.12.2019

**Verified by (Signature)**
**Name & Designation**

**36th Annual Karnataka State Conference** of Association of Otolaryngologists of India & **14th South Zone ENT CONFERENCE 2018** – MIMS, Mandya

AOI SOUTH KCON 2018 MANDYA

# Certificate

*This is to certify that Dr* LATADEVI. H.T

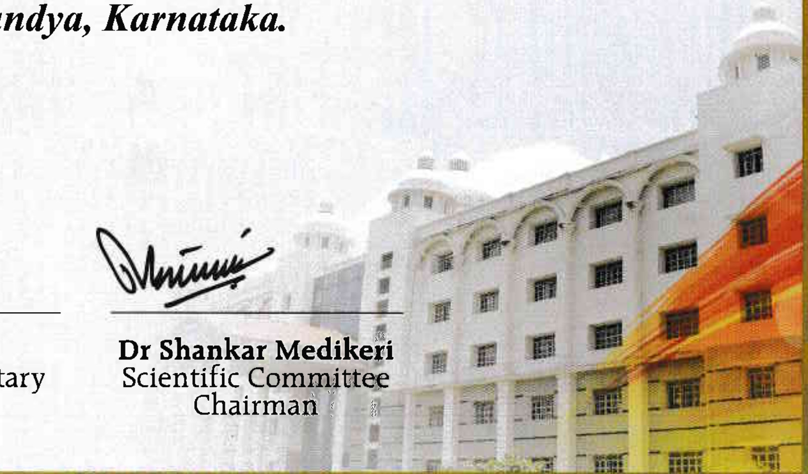
*of* BIJAPUR *has participated in the conference as a*

*Chairperson/Moderator/Panelist/Speaker in one of the Panel Discussion/Symposium*

*Instructional Session/Crossfire/Invited Talk* Acoustic Analysis of Normal and Abnormal Indian voices - An Otolaryngologists' Perspective

*at the* ***36th Annual Karnataka State & 14th South Zone ENT Conference***

*held from* ***11th - 14th October-2018 at MIMS, Mandya, Karnataka.***



| | | | | |
|---|---|---|---|---|
| **Dr A M Shivkumar**<br>AOI Karnataka State<br>President | **Dr Jyothiswarup**<br>AOI Karnataka<br>Secretory | **Dr M Hanumanth Prasad**<br>Organising Chairman | **Dr Ravi.D**<br>Organising Secretary | **Dr Shankar Medikeri**<br>Scientific Committee<br>Chairman |

# 37TH AOIKCON 2019 MADIKERI

## 27th, 28th & 29th September 2019

**Organised by**

**AOI Kodagu under the aegis of AOI Karnataka**
**&**
**Kodagu Institute of Medical Sciences**

## CERTIFICATE OF PARTICIPATION

This is to certify that

**Dr H.T. LATHA DEVI**

has participated a PAPER titled

**ASSESSMENT OF NORMAL HUMAN VOICE - AN OVERVIEW OF VOICE PARAMETERS**

in the **Dr. S. K Mondal Gold Medal For Best Paper Presentation**

in the 37th Karnataka State ENT Conference 2019 held from 27th to 29th September 2019 at Kodagu Institute of Medical Sciences.

| | | | | |
|---|---|---|---|---|
| **Dr. Mohan Appaji** | **Dr. Vishwas K** | **Dr. Shwetha** | **Dr. Dhanraj G A** | **Dr. Deepak Haldipur** |
| President, AOI Karnataka<br>Organising Chairperson,<br>AOIKCON 2019 | Co - Organising Chairperson,<br>AOIKCON 2019 | Organising Secretary,<br>AOIKCON 2019 | Secretary, AOI Karnataka<br>Co - Organising Secretary<br>AOIKCON 2019 | Patron, AOIKCON 2019 |

## PROFORMA

Subject ID : ................................ Date : ................................

First Name : ..........................Middle Name : ..........................Last Name : ..........................

Age : .......................... Gender : .......................... Phone No : ..........................

Address : ........................................................................................................................

........................................................................................................................

........................................................................................................................

........................................................................................................................

Present History – any complaints :

Past History :

Personal History :

Any Previous Treatment History :

General Physical Examination :

Pulse : ...................... BP : ...................... Temperature : ...................... RR : ......................

INDIRECT LARYNGOSCOPY.................

CVS Examination :

RS Examination :

CNS Examination :

PA Examination :

Any Other Information :

| **Voice Parameters** | |
|---|---|
| Acoustic measures | |
| Pitch<br><br>Mean SD Maximum minimum | |
| Jitter:<br><br>Mean SD Maximum minimum | |
| Shimmer:<br><br>Mean SD Maximum minimum | |
| Spectral tilt: | |
| Noise Energy: | |
| Formant Flutter. | |
| Harmonics – to noise ratio:<br><br>Mean SD Maximum minimum` | |
| Spectrogram: | |

Remarks

B.L.D.E. UNIVERSITY

Department of Otorhinolaryngology & Head and Neck Surgery

**RESEARCH CONSENT FORM**

*Title of the Research Project* : Development of a tool to objectively identify normal human voice

*Name of the Researcher* : Dr. H.T.Lathadevi. Professor

1. *Purpose of the Project*

This study will be useful academically as well as clinically to know about characterstics of human voice.

2. *Procedure*

understand that, the procedure of the study will involve evaluation of various physiological/ physical parameters. The procedure will not interfere with any of my physiological parameters and they are non-invasive.

3. *Risk And Discomforts*

I understand determination of these voice parameters will not cause any risk to my health.

4. *Benefits*

I understand that my participation in the study may not have any benefit to me but this may have a potential beneficial effect in the field of laryngology

5. *Confidentiality*

I understand that medical information produced by this study will become part of institutional records and will be subject to the confidentially and regulation of the said institute. Information of a sensitive personal nature will be not be part of medical record, but will be stored in investigators research file and identified only by a code number. The code key connecting two numbers will be kept in a separate secured location.

If data are used for publication in the medical literature and publishing purpose no names will be used and other identities such as photographs, audio and video tapes will be used only with my special written permission. I understand I may see the photographs and the video tapes and have the audio taps before giving permission.

6. *Request For More Information*

I understand that may ask that more questions about the study at any time I will be informed any significant new finding discovered during the study.

7. *Refusal Or Withdrawl Of Participation*

My participation is voluntary and I may refuse or withdraw my consent and discontinue participation in the study. I also understand researcher may terminate my participation at any time.

8. I understand that by my agreement to participate in this study I am not waiving any of my legal rights.

I confirm that *Dr. H.T.Lathadevi* (Researcher) has explained to me all the above facts thoroughly in my own language and therefore I agree to give consent to participate as a subject and this research project.

Date : ..........................

Signature of the Participant

Original Research Article Medical

International Journal of Pharma and Bio Sciences

ISSN
0975-6299

# CREATION OF VOICE DATABASE, ACOUSTIC ANALYSIS AND STANDARDISATION OF NORMAL INDIAN VOICES

**LATHADEVI H T*[1], MALIPATIL SR[2], S P GUGGARIGOUDAR[3]**

*[1,2,3]*Department of Otolaryngology and H& N Surgery, BLDE University's Shri BM Patil Medical College & Hospital, Vijaypur, Karnataka, India..*

## ABSTRACT

Acoustic analysis is used to assist differential diagnosis, documentation and evaluation of treatment for voice disorders. Clinical data have shown that jitter and simmer are indices of voice pathology or perceptual hoarseness but are more commonly used as an outcome measure.A voice with some periodicity can now be analyzed with a computerized acoustic analyzer, a relatively newer technique that can be widely used in the clinical practice.The purpose of the study was to create a normative Indian voice database and propose a standardization for normal acoustic parameters for Indian voices. 1000 Normal voice samples were collected from college students (male and female) aged 18-28 yrs. A sustained vowel /a/ was recorded and analyzed for parameters like Jitter, Shimmer, Harmonic noise ratio and Fundamental frequency (Fo) using a software. The Mean, SD, range of the voice parameters were calculated from the sample voices. The value of ranges of mean Jitter was 0.00 to 0.03635, mean Shimmerwas 0.06 to 0.2506 and Harmonic Noise Ratio was 8.31 to 30.73db.

**KEYWORDS:** ***Voice database, acoustic analysis, parameters of normal voice.***

**LATHADEVI H T***

**Department of Otolaryngology and H& N Surgery, BLDE University's**
**Shri BM Patil Medical College & Hospital, Vijaypur, Karnataka, India.**

**Received on: 12-12-2016**
**Revised and Accepted on: 09-03-2017**
**DOI: http://dx.doi.org/10.22376/ijpbs.2017.8.2.b349-354**

## INTRODUCTION

Communication and expression through sound are found in most of the animals. However, it is a highly sophisticated and complex skill in humans. Spoken speech is the verbal communication that realizes the language in to sound output. This skill is acquired laboriously throughout the growth of the child into adulthood.Voice is the continuous sound produced by vocal cords that provides the basic sound to the organs of articulation which modulate it and finally produce speech. Essentially voice is the acoustic output of the vibrations of the vocal cords and the coloring of this output by the vocal tract.The sound of each individual's voice is his/her signature that is, entirely unique not only because of the actual shape and size of an individual's vocal cords but also due to the size and shape of the rest of that person's body, especially the vocal tract, and the manner in which the speech sounds are habitually formed and articulated. The voice gets affected when there is change in the architecture or the function of any of the above mentioned organs. An abnormal voice is variously described as hoarse, husky, breathy, harsh, rough etc. Moreover, our voices change throughout our lifetime, but there are also minor, and sometimes major, fluctuations throughout a day. Still, we are capable of differentiating normal voices from abnormal ones. But there is no universal, objective way of telling the exact difference between normal and abnormal voices. Since voice is essentially an acoustic output, it is possible to analyze its physical characteristics. It is logical to assume that our brain uses specific acoustic parameters to decide whether the voice is normal. The present study attempts to create a large database of normal voices, extract their physical parameters and statistically recognize the determinants of a normal voice.

### *Physiology of voice production*

Voice is produced by vibration of vocal cords which produce the fundamental note. This is modified by the so called vocal tract which includes throat, nose and mouth. In fact, vocal tract is a series of acoustic filters which reinforce or decrease the original fundamental note.These filters are capable of assuming different shapes of varying sizesin oral and pharyngeal cavities. These changes in shape produce characteristic formants which distinguish one vowel from other. For example, the vowel [a:] have frequency bands in the region of 800 Hz and 1100 Hz.

### *Phonation*

The Myoelastic- Aerodynamic theory or tonic theory (Van den Berg)[1] is generally regarded as the most widely accepted model to explain the mechanics of voice. According to this theory, when the vocal folds adduct in the midline due to action of interarytenoid muscle, there is build up of subglottic pressure. This causes the vocal fold to separate. When they adduct due to elastic recoil, the velocity of airflow increases in between vocal cords and the pressure between the vocal folds decrease (Bernoulli's principle). The decreased air pressure coupled with elastic recoil of vocal folds causes them to move back to midline. This is one cycle of vibration which repeats approximately 125 Hz in males and 225 Hz in females.This was questioned by Husson[2] who put forward his neuromuscular neurochronaxic or clonic theory of vocal fold vibration. They contended that every single vibration of the vocal cords was due to an impulse from the recurrent laryngeal nerves and the acoustic centre in the brain regulated the of vocal fold vibration. But this theory was disproved effectively. The problems with this theory was that theleft laryngeal nerve to vocal fold has a longer pathway/course than the right one; so nerve impulses should take longer than the right side; this means that vocal folds should vibrate out of phase which is not so.When tracheostomy is done the phonation does not occur even with effect the neural impulses - this means that air pressure is a component to phonation and not just neural impulses.Hence the voice requires a power source (lungs, abdominal muscles and back muscles), Oscillator (vocal folds) and resonator (vocal tract which includes oral cavity, oropharynx, supraglottis etc.)

## MATERIALS AND METHODS

### *Collection of test subjects*

Young healthy adults, between the age of 18 and 28 years, both male and female were selected for the study. All of them gave an informed consent. They underwent thorough clinical evaluation and those having any pathological condition or even suspicion of it were excluded. They were subjected to assessment of their voices by a speech therapist and an ENT surgeon. Only those who were certified as having normal voice were selected for the study. Finally there were 1000 tests subjects left.

### *Training and Recording of Voice Samples*

Each person was first trained to produce a sustained vowel 'a' at comfortable loudness and pitch.

### *Recording*

Recordings were made in a sound-treated chamber using a unidirectional microphone (Sony Audio-Technical 250XL) at a distance of 5cm in front of the lips. The sustained /a/ vowel signal was recorded for minimum of 3 seconds using the application PRAAT[3] version 5.4.04. The intensity was controlled using the VU meter built into PRAAT. The sustained vowel is preferred over regular speech in vocal acoustic assessment as it provides more reliable results.[4,5]

### *Sampling*

A spectrograph of each sample was extracted and the most stable and uniform 1 sec slice was selected and saved as a sound file. A PRAAT script was developed that could batch process all files into a folder to extract four parameters i.e., Jitter, Shimmer, Harmonic Noise Ratio and Fundamental Frequency and out to an excel sheet. Each parameter was analyzed for different variations like mean, SD, range, etc. These ranges of parameters were compared with other normative data. All the parameters were determined with 95% confidence interval.

## RESULTS

**Table1**
***Voice parameters obtained from acoustic analysis***

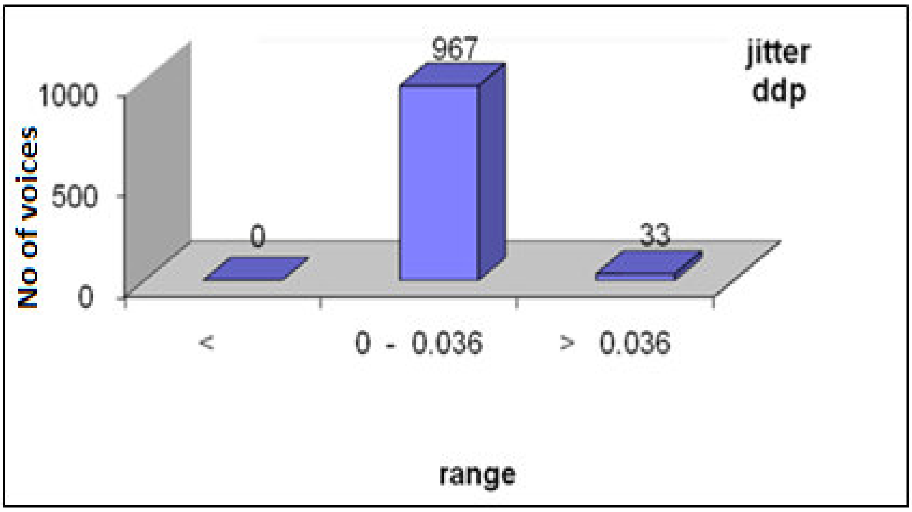
| Parameter | Mean +/-1.96 SD 95%confidence interval |
|---|---|
| F0, fundamental frequency | 201 to 928 hz |
| Jitter (ddp) | 0 to 0.036352484 |
| Shimmer(dda) | 0.063955802 to 0.250624922 |
| HNR (Harmonic noise ratio) | 8.31738dB to 31.738Db |

The Table.1 gives the total range of the values of the population under study. Especially the range of Fundamental Frequency is more. But the range of parameters like jitter, Shimmer and Harmonic noise ratio is almost same as other studies.

**Table2**
***Studies showing acoustic measures for various authors***

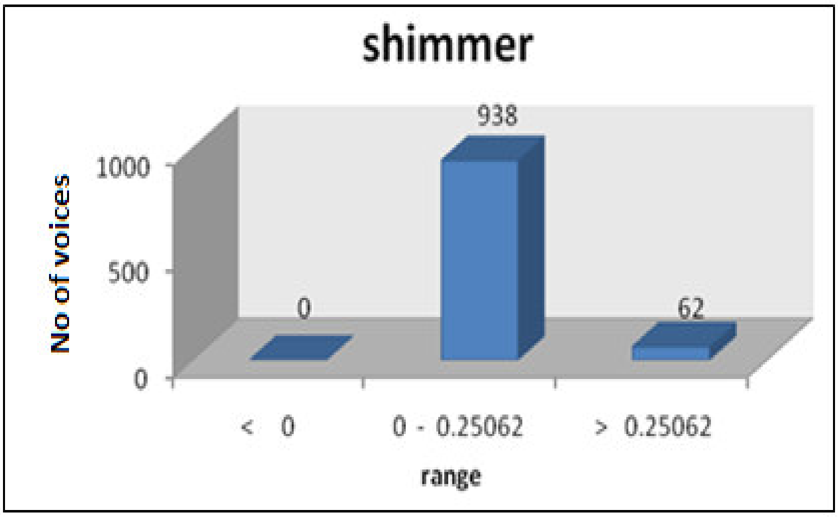
| Sl/No. | Author | Jitter –male | Jitter female | Shimmer- male | Shimmer-Female | HNR-male dB | HNR-female Db | Fo-Male Hz | Fo- female Hz |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Williamson[7] | Less than 1.04% | | Less than 3.81% | | Less than 20 | | 128 | 225 |
| 2, | Simone[8] N=80 | 0.37% | 0-87% | 63.77% | 65.17% | 1.06db | -1.64 | 127.6 | 215.45 |
| 3, | KC TORAN[9] n=50 | 0.14% | 0.14% | 1.6% | 1,6% | 25.81% | 25.88% | 170 | 246.45% |
| 4. | ANC Fillippe[5] 20 m+20f | 0.49 | 0.62 | 0.22 | 0.22 | 9.56 | 10.9 | 119 | 205 |
| 5. | CC Wang[10] 45m+45f | 0.56 | 0.66 | | | | | 118.3 | 203.2 |
| 6. | K Aries[11] N=70 | 0.46% | 0.87% | 0.23% | 2.72% | 0.13 | 0.12 | 130.6 | 218.38 |
| 7. | Bonzi[12] N=72 | 0.36 Local% | 0.31 Local% | 3+/- 0.9 | 2.7+/-1.1 | 20+/-2 | 21+/-3 | | |
| 9 | Lathadevi et Al N=1000 | 0.018176242 | | 0.1572899 | | 20.024 | | 120 | 220 |

**Graph 1**
***Jitter range***



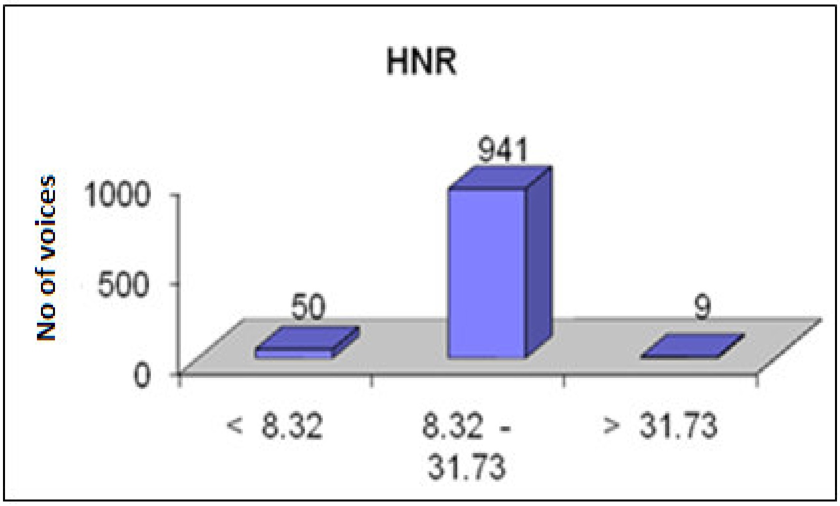

***Graph.1 shows the number of voice population falling within the range of quoted range of jitter values. For e.g.The 967 voice samples have a range of 0.0 to 0.036Hz jitter.***

**Graph2**
***Shimmer range***



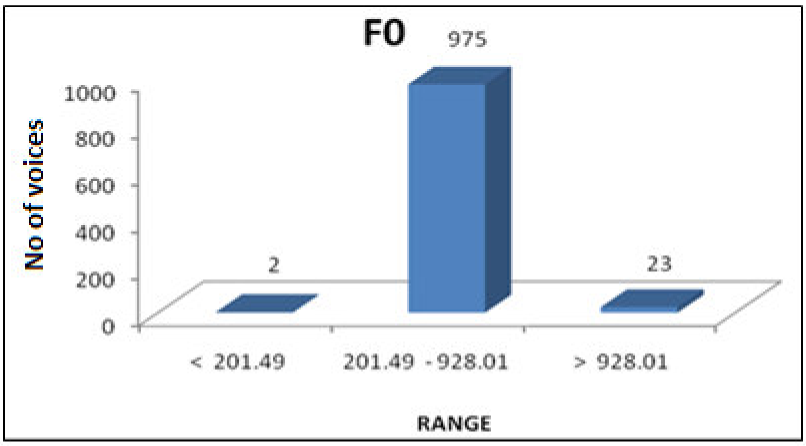

***Graph.2 shows the number of voice population falling within the range of quoted range of shimmer values.The 938 voice samples have a range of 0.0 to 0.25062 shimmer.***

**Graph 3**
***HNR RATIO***




**Graph.3 shows the number of voice population falling within the range of quoted range of HNR values.The 941 voice samples have a range of 8.32 to 31.73dB.**

**Graph 4**
**Frequency Range F0**




***Graph.4 shows the number of voice population falling within the range of quoted range of Frequency values.***

## DISCUSSIONS

Voice assessment which was subjective so long has now been aided by objective analysis tools. This is essentially due to the advances made in precise sound capturing equipment and fast and accurate acoustic analysis software. Since the methods are simple and non-invasive they are being used widely throughout the world. A number of acoustic analysis software like Dr Speech, MDVP, PRAAT, and Vaghmi have been developed. Some of them come embedded in dedicated hardware. However, a simple set up can be established with a moderate computer, a good quality microphone and recording software. Some analytical software provides recording facility built into them. A sound treated room is mandatory to avoid extraneous noise and have a faithful recording. This arrangement provides us with extensive physical information about the test sound. The parameters so obtained for a particular sound can be assumed to be specific for that sound. Our hypothesis is that human brain perceives a voice as normal on specific parameters common to all normal voices. The present study aims at statistically finding out such parameters common to all test subjects having normal voice. These can later be used as a yardstick to diferentiate abnormal voices from the normal. There is limited literature available that addresses standardization of parameters of normal voice. Even in available data the number of normal voices was not more than 200[5,8,9,10,11,12]. In our study we have collected 1000 normal voices which would give more dependable results. This database can also serve other researchers as a database repository.From the clinical standpoint of view, assessment of voice signal has become noninvasive, less expensive and commonly available[6]. In our study we have used PRAAT, acoustic analysis software. This is being in a large number of laboratories throughout the world[7].PRAATis an efficient computer software package used for the analysis of speech in phonetics. It is developed by Boersma and Weenink on 1995. It can run on a wide range of operating systems including, Linux, UNIX, Mac and Microsoft Windows. Its latest version is PRAAT 5.3.39. Praat extracts as many as 30 parameters by its voice analysis. However, we have considered F0, jitter, Shimmer and HNR only since many other studies have proved their efficacy[12].Maryn et al[6] (2009:217) as quoted by Williamson[7] compared frequency perturbation (jitter) and amplitude perturbation (Shimmer) measures using both MDVP and PRAAT programs, and both a purpose-built recording system and a personal computer-based system for acoustic voice assessment. Theauthor noted that MDVP consistently yielded higher measures than PRAAT and concluded that "one can hardly compare frequency perturbation outcomes across systems and programs and amplitude perturbation outcomes across systems..."PRAAT software itself can calculate five different measures of jitter and six different measures of Shimmer. However, Graham Williamson[7] et al in his articlestate: "It is difficult to be precise about norms for acoustic measures such as jitter, Shimmer, noise-to-harmonics ratio and fundamental frequency. There are many factors which militate against declaring all-encompassing norms. Some of these are person-specific (e.g. gender and age differences), cultural (e.g. what north Americans may consider to be within normal limits may be different from what north Koreans consider to be typical), and related to the testing environment (e.g. variation in the equipment used, and – importantly – the use of different algorithms in the software programs which are used to make the measurements). Measures of jitter and Shimmer using one software program cannot always be compared directly with measures made by another software program" The following table gives comparison of different values from studies: Bielamowicz et al[13] have compared perturbation measures from C Speech, Computerized Speech Laboratory, SoundScope, and a hand marking voice analysis system and state that "Measures of perturbation in the various analysis packages use different algorithms, provide results in different units, and often yield values for voices that violate the assumption of quasi-periodicity.AA Simone et al[8]state "We assume that comparison of results collected with different vocal acoustic analysis programs can present differences even when using similar measures, owing to differences in algorithms, methods to calculate fundamental frequency, type of microphone used, type of storage of the recorded voice and type of token used, if connected or sustained speech" Areis, et al[11] opine that despite the accuracy and reliability of each machine, authors have agreed to standardize normative data individually due to a number of factors that may cause variations among each system. These possibilities include the type of programming of the acoustic analysis software, the use of recording criteria, type of microphone and other devices used in voice recording. Despite these complications, some authorities do declare so-called thresholds of pathology. For example, the Multi-Dimensional Voice Program (MDVP)(Kay Elemetrics, 2008) indicates a threshold of pathology of <=1.040% for jitter and <=3.810% for Shimmer.The normative Indian voices data was also given by Hemaet Al[14]using MDVP software. About 104 voice samples were used with 54 males and 43 females. The parameters were compared with western voices which showed differences in perturbation measurements. They concluded that these differences are due to change in vocal tract length, mass and tension of vocal tracts.There is a growing international trend for significant technological developments in the field of voice and speech evaluation, especially in the advancement of vocal acoustic analysis software. For this reason, standardization of normal acoustic measures is necessary due to the variation of systems protocols and software algorithms[5].Several acoustic analysis softwares have demonstrated normal and pathological voice conditions. Despite the accuracy and reliability of each machine, authors have agreed to standardize normative data individually due to a number of factors that may cause variations among each system. ANA et al[5] felt that standardization of fundamental frequency measures (f0), jitter, Shimmer and harmonic noise ratio (HNR) for young adults with normal voice is the need of the day. They studied normal voices of 20 males and 20 females. between 20 and 45 years, without signs and symptoms of vocal problems using CSL-4300 Kay-Elemetrics software with vowels /a/ and /é/[2]. Their Results showed that for females, vowels /a/ had average measures of f0 as

205.82 Hz; jitter of 0.62%;Shimmer of 0.22 dB ; HNR of 10.9 dB , respectively. For males, vowel /a/ had average measures of: f0 119.84 Hz; jitter of 0.49% ; Shimmer of 0.22 dB ; HNR 9.56 dB respectively. Both f0 and NHR female measures were significantly higher than their male counterparts. They felt significant differences with other studies. Their findings are given as mean only without range.Acoustic measures for normal adult voices are given by Williamson[7] from PRAAT Software as follows: Percentage of Jitter and Shimmer is to be less than 1.04% and 3.8% respectively. HNR Value is to be less than 20 Db. Fo in males and females as less than 128 and 225 Hz respectively. These normative values are similar in our study. The value of Jitter in our study was 0.018% (Jitter ddp) which is very low when compared to other studies like Bonzi et al[12] of local jitter percentage of 0.36%. Wang[10] was 0.56%, Simone et al[8] was 0.37% (jitter ratio), Kirt et al[11] was 0.46%, Fillippe et al[5] was 0.62% (jitter Avg). When the value of Shimmer (0.1572) was compared with other studies like A Simone et al[8] (2.37 db), Bonzi et al[12] ( local Shimmer%, 3+-0.9) and Toranet al[9] (1.6%), it is found to be low. But studies like Horii[16] (0.132db), Ana et al[5] (0.22db) Aries et al[11] (0.23%) showed similar values.On analysis of HNR value from our study (20 db), it was similar to Bonziet al[12] (20+/-2 db) and Fernandez Leisa et al[15] (18db). It was higher value of 25.81 db in KC Toran et al[9]and very less in ANCFillippeet Al[5] (9.56 db).The comparision of values of parameters show significant differences which necessitate standardization.The purpose of this paper was to state the significance of voice analysis systems in the prediagnosis of certain medical conditions which later may transform into fatal or incurable diseases. The proposal of a voice database, standard voice analysis tool, and method of voice measurement is done. This methodology ensures accuracy, patients' ease, economy and less time consuming in predicting symptoms at early stages. It can be used by any medical practitioner without prior training. Since it is not possible to have a single world standard for normal voice parameters every clinic or laboratory should develop its own standards and use these as benchmark for further comparisons or clinical evaluations.

## CONCLUSION

Acoustic analysis of voices is a simple noninvasive technique which can be effectively carried out easily at any clinic with good accuracy and reasonable prediction of symptoms. It is one of the objective tool for characterization of normal voice that can be used by a clinician. Jitter, Shimmer and Harmonic noise ratio are the parameters measured whose ranges give an idea of normality of the voice.

## CONFLICT OF INTEREST

Conflict of interest declared none.

## REFERENCES


1. Berg VDJ. Myoelastic-aerodynamic theory of voice production. J of Speech and Hearing Res. 1958; 3(1): 227-244.
2. Herbert DH, Dunker E. Husson's Theory; An Experimental Analysis of his Research Data and Conclusions. Arch Otolaryngol, 1967;85(3):303-313.
3. Praat:Doing phonetics by computer.Paul Boersma and Weeninck. Available from http://www.fon.hum.uva.nl/praat/
4. Parsa V, Jamieson DG. Acoustic discrimination of pathological voice: sustained vowels versus continuous speech. J Speech Lang Hear Re., 2001;44(2):327-39.
5. de Felippe AC, Grillo MH, Grechi TH. Standardization of acoustic measures for normal voice patterns. Brazilian journal of otorhinolaryngology. 2006 Oct 31;72(5):659-64.
6. Maryn.Y. Acoustic measurement of overall quality of voice of sustained vowels and continuous speech. 2010[Internet] Available from https://biblio.ugent.be/publication/888156/file/888179.pdf
7. Grahaam Williamson. Acoustic Measures (Norms). Voice. [internet] [cited 01 February 2016]. Available from http://www.sltinfo.com/acoustic-measures-norms/
8. Simone AA. Marcos G. José CP, Marcelo OR.Brazilian Journal of Otorhinolaryngology,2002. 68:4(14), 540-544 availablefromhttp://oldfiles.bjorl.org/conteudo/acervo/acervo_english.asp?id=446
9. Toran KC, Lal BK. Objective analysis of voice in normal young adults. Kathmandu University Medical Journal, 2009; 7( 4): 374-377.
10. Wang CC et al. Voice Acoustic Analysis of Normal Taiwanese Adults. J Chinese Med Assoc. 2004; 67(4):179-184.
11. Kirt AD, Ray C, Fredrick YH. Vocal acoustic measures of Asymptomatic Filipino young adults at a private tertiary Hospital in Quezon city- A pilot study. Philippine J of Otol and H and N Surg. 2012 JulyDec;27(2):12-17.
12. Bonzi EV, Grad GB, Maggi AM. Study of the characteristic parameters of the normal voices of Argentinian speakers.papers in Physics.2014;6 (1)23-25.
13. Bielamowicz S, Kreiman J, Gerratt BR, Dauer MS, Berke GS. Comparison of voice analysis systems for perturbation measurement. J of Spch and Hear Res. 1996 Feb;39(1):126-34.
14. Hema N.; Mahesh, Sangeetha; Pushpavathi, M. Normative Data for Multi-Dimensional Voice Program(MDVP) for Adults - A Computerized Voice Analysis System. J of the All India Institute of Spch& Hear. 2009; 2 ( 28): 1-5.
15. Fernández LR et Al, Acoustic analysis of the normal voice in nonsmoking adults. Actaotolaryngolespanol. 1999;50(2):134-4.

## Reviewers of this article


**Dr.R.M.Karadi, M.S. (ENT)**

Prefessor & HOD, Department of ENT,
Shri B. M. Patil Medical College, Bijapur,
India

**Asst.Prof.Dr. Sujata Bhattacharya**

Assistant Professor, School of Biological and Environmental Sciences, Shoolini University, Solan (HP)-173212, India

**Prof.Dr.K.Suriaprabha**

Asst. Editor , International Journal of Pharma and Bio sciences.

**Prof.P.Muthuprasanna**

Managing Editor , International Journal of Pharma and Bio sciences.


We sincerely thank the above reviewers for peer reviewing the manuscript

DOI: 10.7860/JCDR/2018/36782.12310

Original Article

Ear, Nose and Throat Section

# Objective Acoustic Analysis and Comparison of Normal and Abnormal Voices

HT LATHADEVI[1], SURESH PUNDALIKAPPA GUGGARIGOUDAR[2]


## ABSTRACT

**Introduction:** Acoustic analysis is commonly used to diagnose, document and treat voice disorders. Type I and Type II voices which are nearly periodic can be easily assessed with computerised acoustic analysers. Widely used voice parameters like Jitter, Shimmer and Harmonic Noise Ratio (HNR) are indices of voice pathology and indicate different diseases and help as an outcome measure.

**Aim:** To study whether objective acoustic analysis is able to differentiate between abnormal and normal voices.

**Materials and Methods:** In the present study, the patients were made to phonate sustained vowel /a/ and the voice was recorded to analyse parameters like Jitter (ddp), Shimmer (dda), HNR and Median pitch using the acoustic software, PRAAT. These parameters were compared with the values of the institute's own normal voice database. They were analysed for Mean, Median, standard error of mean, and Kolmogorov-Smironov values.

**Results:** The range of abnormal voice parameters like Jitter (ddp), shimmer (dda), median pitch and HNR measures were different from normal voices. The difference was significant in jitter (p-value of 0.026) in males, in Shimmer (p-value of 0.035) in females. HNR did not show any significance.

**Conclusion:** The traditional methods of perturbation measures like Jitter, Shimmer, Median pitch and HNR can help the clinicians for characterisation of voice into either normal or abnormal voices. But the comparison needs a local or regional normal voice database.


**Keywords:** Hoarseness of voice, Voice assessment, Voice disorder

## INTRODUCTION

Assessment of vocal function has been a challenge to clinician since time immemorial. Two approaches are used for the same, the perceptual and objective measurement based analysis. The perceptual assessment involves listening to patient's voice production. This is performed by an expert jury and hence is a subjective measure of assessment. The objective assessment is done by using computerized software which requires acoustic, aerodynamic measures through complex medical equipments like laryngoscopy, stroboscopy, electroglottography etc. Visual methods like these are important tools in basic voice research but have several limitations. Acoustic analysis appears to have an advantage over others because of its noninvasive nature and its potential for providing quantitative data with reasonable expenditure of analysis time [1].

The development of simpler and portable instrumentation for acoustic analysis would lead to programs similar to audiometric testing in schools and industry. Such instrumentation can have large benefits in terms of overall health maintenance [2]. The acoustic parameters like fundamental frequency, Median pitch, jitter, shimmer and HNR are useful in describing vocal characteristics. These parameters change e.g., Jitter has a typical value of variation behaviour 0.5% to 1% for sustained phonation in young adults [3]. Shimmer changes in breathiness and mass lesions of vocal cord. The values become altered in adults upto 3% and 1% in children [4]. The HNR ratio depends on periodic and non-periodic components of a segment of voiced speech and represented by dB. A value less than 7 dB is considered abnormal [5].

Usually, these voice parameters are measured at a well-equipped voice lab maintained by speech pathologists. But here, we have showed the way of assessing the voice objectively using easily accessible recording equipments and PRAAT software unlike other studies where they use customised voice lab equipments (Dr. Speech, MDVP CSL Speech etc.,) which are of high cost.

The normal voice database from these voice labs may not correlate with local population as the voices are influenced not only by the person, age, sex, time of the day, emotions of the person, disease but also by locality and region [6]. Most of them have felt that more regional databases and abnormal voice comparisons are necessary [7]. Besides, each health institution should have its own voice assessment protocol with its recording equipment and software for patient services and research. As there are no local databases or prior studies from our region, we felt the need of voice database and created the same. Therefore, the present study was conducted and abnormal voices were compared with the normal voices.

## MATERIALS AND METHODS

This was a prospective comparative study wherein normal voices and abnormal voices were collected at Department of ENT, BLDE (Deemed to be University) Shri BM Patil Medical College, Hospital and Research Centre, Vijaypur, Karnataka, India. The study was conducted from March 2016 to Feb 2017. Ethical clearance was taken from the Institutional Ethical Clearance Committee (ECR/383/INST/KA/2013/RR-16). After getting informed consent from each person, they underwent thorough clinical evaluation by ENT surgeon.

With anticipated least difference of means of study variable between the cases and control groups as 0.0185 and anticipated SD (standard deviation) as 0.0236, with 90% power and 5% level of significance, the minimum sample of 43 under each group was calculated.

### Collection of Normal Voice Samples

A total of 43 normal voices were collected from the database of young healthy adults between age of 18 to 28 years, of which 23 were males and 20 were females. Any person having history of smoking or any other pathological conditions which made them unfit for the study were excluded.

### Collection of Abnormal (Pathological) Voices

Forty-three patients (23 males and 20 females) between 18 to 55 years presenting with hoarseness and lesions of larynx like vocal nodules, vocal polyps, chronic laryngitis, voice abuse, early glottis carcinoma etc., were selected during the study.

### Recording of Voices

Voices were recorded in a sound treated chamber using a unidirectional microphone (Sony Audio technical 250*L). The sustained /a/ vowel signal was recorded for three seconds, using PRAAT version 5.4.04 [8]. The intensity was controlled using VU meter built into PRAAT. From the recorded sample voice of three seconds duration, sampling frequency of 44100 Hz, spectrograph was extracted and the more stable and uniform one second was selected and saved as a sound file. A PRAAT script was written which can batch process all files into a folder to extract four parameters, Jitter (ddp), Shimmer (dda), Harmonic Noise Ratio (HNR) and Median pitch.

## STATISTICAL ANALYSIS

These parameters were analysed for different variations like Mean, standard error of mean and Kolmogorov-Smirnov ZH values. Median Pitch, Jitter, Shimmer, and HNR between normal and abnormal voice groups of males and females were compared. The level of significance was set at 5% ($p<0.05$) with SPSS Version 23.

## RESULTS

The values of Mean, standard error of mean, and Kolmogorov-Smirnov ZH values of Median Pitch, Jitter, Shimmer, and HNR between normal and abnormal voice groups of males are given. The Jitter had a p-value of 0.026 which was significant but Median pitch, HNR and shimmer did not show the significance [Table/Fig-1].

When the Mean, standard error of mean, and Kolmogorov-Smirnov ZH values of Median Pitch, Jitter, Shimmer, and HNR of females were compared between normal and abnormal voice groups, the shimmer had a p-value of 0.035 which was significant but Jitter, Median pitch and HNR did not show the significance [Table/Fig-2].

## DISCUSSION

Voice is a multidimensional measure which requires various methods for its assessment like Perceptional measures, acoustic analysis, aerodynamic measures, video-stroboscopy, non-linear dynamic measures etc. The objective of the present study was to compare voice parameters of abnormal voices with normal voices. This study also shows that with the availability of freely downloadable software like PRAAT, ENT surgeons and Speech pathologists can easily use the software to analyse the voice effectively.

As early as 1987, Baken RJ had given details about few valid techniques for acoustic assessment of vocal dysfuction which are easily accomplished with current instrumentation [9]. Leiberman P recorded 23 voices from the speakers who had pathologic growths on their vocal cords. It was found that they had larger perturbations than did normal speakers with the same median fundamental periods. This may be related to size of pathological growth [10]. This showed that study of perturbation measures is important for assessment of voice. Hence voice parameters like Jitter (Leiberman P), shimmer (Horii Y), and harmonics-to-noise ratio (Yumoto E et al.,) were extensively studied [10-12]. A study by Hillman RE et al., demonstrated that acoustic measures alone could be highly accurate in determining the presence/absence of a voice disorder [13]. According to Eskenazi L et al., the two most useful parameters for predicting vocal quality were the Pitch Amplitude (PA) and the HNR [14].

Many authors studied both normal and pathological voices using the parameters like jitter, shimmer, and HNR. Di Nicola V et al., studied 208 subjects (148 with dysphonia and 60 normal) using computerised digital sonography [15]. HNR developed by Yumoto E et al., was analysed and found to be highly sensitive as values were different in dysphonic patients. The comparison between the average HNR recorded in those patients (1.697 dB) is significantly different from that recorded in the normal subjects (11.169 dB) ($p<0.001$ [12].

A similar study was done for voice analysis by Bielamowicz S et al., using C Speech, Computerized Speech Laboratory, SoundScope, and a hand marking voice analysis system. Sustained vowels from 29 male and 21 female speakers with mild to severe dysphonia were used. They felt that measures of perturbation in the various analysis packages use different algorithms, provide results in different units, and often yield values for voices that violate the assumption of quasi-periodicity. As a result, poor rank order correlations between programs using similar measures of perturbation were noted [16]. Their sample size is almost same as this study.

| Variables | Normal (N=23) | | | | Abnormal (N=23) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | SE of Mean | Min | Max | Mean | SE of Mean | Kolmogorov-Smirnov ZH | p-value |
| Median Pitch | 94.41 | 616.32 | 181.59 | 29.34 | 90.07 | 469.49 | 178.64 | 18.21 | 0.74 | 0.649 |
| Jitter (ddp) | 0.002 | 0.029 | 0.014 | 0.002 | 0.002 | 0.153 | 0.033 | 0.008 | 1.47 | 0.026* |
| Shimmer (dda) | 0.011 | 0.244 | 0.115 | 0.013 | 0.017 | 0.311 | 0.141 | 0.019 | 0.89 | 0.414 |
| H/N Ratio | 1.41 | 27.79 | 14.14 | 2.13 | 1.36 | 21.70 | 13.06 | 1.41 | 1.18 | 0.124 |

**[Table/Fig-1]:** Mean, standard error of mean, and Kolmogorov-Smirnov ZH values of Median. Pitch, Jitter, Shimmer, and H/N ratio between normal and abnormal voice groups among males.
*significant at 5% level of significance ($p<0.05$)

| Variables | Normal (N=20) | | | | Abnormal (N=20) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Mean | SE of Mean | Min | Max | Mean | SE of Mean | Kolmogorov-Smirnov ZH | p-value |
| Median Pitch | 100.00 | 516.32 | 216.93 | 23.61 | 146.72 | 249.62 | 202.97 | 6.77 | 1.11 | 0.172 |
| Jitter (ddp) | 0.002 | 0.040 | 0.014 | 0.002 | 0.004 | 0.119 | 0.031 | 0.007 | 0.95 | 0.329 |
| Shimmer (dda) | 0.014 | 0.149 | 0.077 | 0.009 | 0.038 | 0.386 | 0.148 | 0.023 | 1.42 | 0.035* |
| H/N Ratio | 1.36 | 27.79 | 14.64 | 1.94 | 1.73 | 27.79 | 14.22 | 1.47 | 0.791 | 0.56 |

**[Table/Fig-2]:** Mean, standard error of mean, and Kolmogorov-Smirnov ZH values of Median Pitch, Jitter, Shimmer, and H/N ratio between normal and abnormal voice groups among females.
*significant at 5% level of significance ($p<0.05$)

In this study Mean, standard error of mean, and Kolmogorov-Smirnov ZH values of Median Pitch, Jitter, Shimmer, and HNR were compared between normal and abnormal voice groups.

When the above parameters were compared among normal and abnormal male voices, the value of Jitter (ddp) was significant (p-value was 0.026, i.e., p<0.05). Median pitch, Shimmer (dda) and HNR values were different but not significant. (p-values were 0.649, 0.414 and 0.124 respectively).

When these parameters were compared among female normal and abnormal voices, shimmer values were significant. (p-value was 0.035 i.e., p<0.05).

Limitations are present for acoustic analysis when it comes to assess aperiodic voices. Titze IR discusses three types of voices depending on the periodicity of the voices. While types 1 and 2 have relatively better periodicity, the type 3 voices have aperiodic waves [17]. Type 3 voices pose problems on correctly analysing the voice parameters. In fact recently, the study by Núñez Batalla F et al., showed that there is no difference between using PRAAT and Dr. Speech for analysis of type 3 voices. Even PRAAT can analyse effectively type 3 voices [18].

Many authors felt other methods like nonlinear dynamic measures are more indicative of differentiation in such cases particularly in chaotic voices. Jacqueline BF et al., studied voices of Indian population comprising adults and elderly. They concluded that parameters like correlation dimension D2 (a voice measure of nonlinear dynamic analysis) are better assessors. The anatomical alterations in the vocal mechanism that occur for any pathological conditions result in higher values of correlation dimension. Thus, it can be considered as a useful tool in the assessment of voice. However, they also felt that the existing voice analysis techniques available to the voice clinician cannot be replaced but nonlinear measures can be added to the existing battery of tests [19].

In this study, comparison of the recorded abnormal voice parameters were done with normal voices and added to a voice database. This normal database is continuously added with voices recorded at our institution which naturally reflects the local sample population effectively. The same authors also proposed an institutional voice database, standard voice analysis tool, and method of voice measurement [7].

According to Stemple JC et al., normal database should report demographic details of their local sample populations to account for factors that influence the instrumental results such as gender, age, health history and local database [20]. Recording techniques and sample tasks may vary across the studies as well as equipment and analysis routines [21]. These factors limit the ability to compare different findings. A practical solution is to collect local norms by measuring a large group of normal speakers as a separate sample.

Di Nicola V et al., on comparison of normal and abnormal voices, felt that forensic evaluation of dysphonia needs application of strict, precise, correct sampling and analysis method following well-defined rules. Further comparison of normal and abnormal voices, HNR was analysed and found to be highly sensitive [15].

Jiang et al., examined objective acoustic analysis methods nonlinear dynamic and traditional perturbation measures like jitter and shimmer, to assess voices of patients with vocal nodules and polyps [22]. The jitter or shimmer showed no significant changes but correlation dimension, a parameter of nonlinear dynamic measure of voice showed significance. They concluded that the combination of traditional perturbation and nonlinear dynamic measures may improve our ability to provide objective clinical analysis of voices with vocal mass lesions.

The cost of these analysis programs is undoubtedly high and routine use by clinicians is not possible. However, development of free computer application with widest diffusion like PRAAT has greater capabilities of analysing acoustic signals [18]. The authors also recommend PRAAT program as valid, reliable, and easily manageable and has minimum equipment requirements.

More and more normal and abnormal voices from local area are to be added to institutional voice database. This helps in overcoming bias and adds to further research on voice assessment.

## LIMITATION

The age range of normal voice study cases were 18-28 years whereas that of abnormal voice were between 18-55 years. This happened because abnormal voices were more common in older age group. The sample size is small. Hence, age difference was not taken into consideration. Though the collected sample size was 63 abnormal voices (32 males and 31 females) only 43 voice files could be assessed by the program. Remaining 20 voice files became corrupted and were not analysed by PRAAT Program. The future studies are to be done on a relatively larger number of subjects from a variety of dysphonia population so that changes in parameters in each specific pathology can be defined.

## CONCLUSION

Acoustic voice analysis is still a valuable technique which enables voice clinicians to compare voices to differentiate them into normal and abnormal. But this requires a robust normal database of the local and regional demographic voice samples as the recording techniques, equipments, age, sex and analysis programs differ from one another. This method can provide a non-invasive and objective tool to identify and document abnormal voices.

## REFERENCES


[1] Davis SB. Acoustic characteristics of normal and pathological voices. Elsevier. 1979;1:271-335. Available at https://doi.org/10.1016/B978-0-12-608601-0.50010-3.

[2] Moore GP. Terminal Report for a conference and early detection of laryngeal pathology, Gainsville; University of Florida, Department of Speech, Communication Sciences Laborotaries. 1973.

[3] Teixeira JP, Oliveira C, Lopes C. Vocal acoustic analysis-jitter, shimmer and HNR parameters. Procedia Technology. Elsevier. 2013;9:1112-22.

[4] Guimaraes, I. A Ciencia e a Arte da Voz Humana. Escola Superior de saude de Alcoitao, 2007*.

[5] Boersma P. Accurate short-term analysis of the fundamental frequency and the harmonics to noise ratio of a sampled sound. IFA proceedings. 1993;17:97-110.

[6] Bonzi EV, Grad GB, Maggi AM, Munoz MR. Study of the characteristic parameters of normal voices of Argentinian speakers. Papers in Physics. 2014;6:art. 060002.

[7] Lathadevi HT, Malipatil SR, Guggarigoudar SP. Creation of voice database, acoustic analysis and standardisation of normal Indian voices. Int J Pharma & Biosciences. 2017;8(2):(B)349-55.

[8] Paul Boerasma, David weenick. Praat : Doing phonetics by computer [Home page internet] No date. Available from http://www.fon.hum.uva.nl/praat/

[9] Baken RJ, Orrikloff RF. Clinical examination of speech and voice. San Diego. Singular Thomson Learning ; 2000.

[10] Leiberman P. Some acoustic measures of fundamental periodicity of normal and pathologic larynges. The Journal of the Acoustical Society of America. 1963;35:344. https://doi.org/10.1121/1.1918465

[11] Horii Y. Fundamental frequency perturbation observed in sustained phonation. J of Speech and Hearing Res. 1979;22(1):5-19.

[12] Yumoto E, Sasaki Y, Okamura H. Harmonics-to-noise ratio and psychophysical measurement of the degree of hoarseness. J Speech Hear Res. 1984;27(1):2-6.

[13] Hillman RE, Montgomery WW, Zeitels SM. Appropriate use of objective measures of vocal function in the multidisciplinary management of voice disorders. Current Opinion in Otolaryngology & Head and Neck Surgery. 1997;5:172-75.

[14] Eskenazi L, Childers DG, Hicks DM. Acoustic correlates of voice quality. J Speech Hear Res.1990;33(2):298-306.

[15] Di Nicola V, Fiorella ML, Luperto P, Staffieri A, Fiorella R. Objective evaluation of dysphonia. Possibilities and limitations. Acta Otorhinolaryngol Ital. 2001;21(1):10-21.

[16] Bielamowicz S, Kreiman J, Gerratt BR, Dauer MS, Berke GS. Comparison of voice analysis systems for perturbation measurement. J Speech Hear Res. 1996;39(1):126-34.
[17] Titze IR. Workshop on acoustic voice analysis: Summary statement. National Centre for Voice and Speech. 1995.
[18] Núñez Batalla F, González Márquez R, Peláez González MB, González Laborda I, Fernández Fernández M, Morato Galán M. Acoustic voice analysis using the praat program: comparative study with the dr. speech program. Acta Otorrinolaringol Esp. 2014;65(3):170-76.
[19] Jacqueline BF, Balasubramanium RK, Pitchaimuthu AN, Bhat JS. Nonlinear dynamic analysis of voice: A normative study in the Indian population. Int J Med Res & Health Sci. 2014;3(1):128-32.
[20] Stemple JC, Roy N, Klaben B. Clinical voice pathology: Theory and management, 5th edn. Plural Publishing, 28-Jan-2014-468.
[21] Vogel AP, Morgan AT. Factors affecting the quality of sound recording for speech and voice analysis. International Journal of Speech-Language Pathology. 2009;11(6):431-37.
[22] Jiang JJ, Zhang Y, MacCallum J, Sprecher A, Zhou L. Objective acoustic analysis of pathological voices from patients with vocal nodules and polyps. Folia Phoniatr Log op. 2009;61(6):342-49.

**PARTICULARS OF CONTRIBUTORS:**
1. Professor, Department of ENT, BLDE University's (DT) Sri BM Patil's Medical College, Hospital and Research Centre, Vijayapur, Karnataka, India.
2. Professor, Department of ENT, BLDE University's (DT) Sri BM Patil's Medical College, Hospital and Research Centre, Vijayapur, Karnataka, India.

**NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:**
Dr. HT Lathadevi,
Professor, Department of ENT, BLDE University's (DT) Sri BM Patil's Medical College, Hospital and Research Centre,
Vijayapur-586103, Karnataka, India.
E-mail: lathadevi45@gmail.com

**FINANCIAL OR OTHER COMPETING INTERESTS:** None.

Date of Submission: **Apr 14, 2018**
Date of Peer Review: **May 08, 2018**
Date of Acceptance: **Sep 22, 2018**
Date of Publishing: **Dec 01, 2018**