VOICE CHARACTERISTICS IN

THIRD TRIMESTER PREGNANT WOMEN

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Register No.: 16SLP031

A Dissertation Submitted in Part Fulfilment of Degree of

Master of Science (Speech-Language Pathology)

University of Mysore, Mysuru

ALL INDIA INSTITUTE OF SPEECH AND HEARING,

MANASAGANGOTHRI, MYSURU - 570006

APRIL 2018

CERTIFICATE

This is to certify that this dissertation entitled **"*Voice characteristics in third trimester pregnant women*"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 16SLP031. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
April 2018

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CERTIFICATE

This is to certify that this dissertation entitled **"*Voice characteristics in third trimester pregnant women*"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student (Registration Number: 16SLP031). This has been carried out under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"*Voice characteristics in third trimester pregnant women*"** is the result of my own study under the guidance of Dr. T. Jayakumar, Reader in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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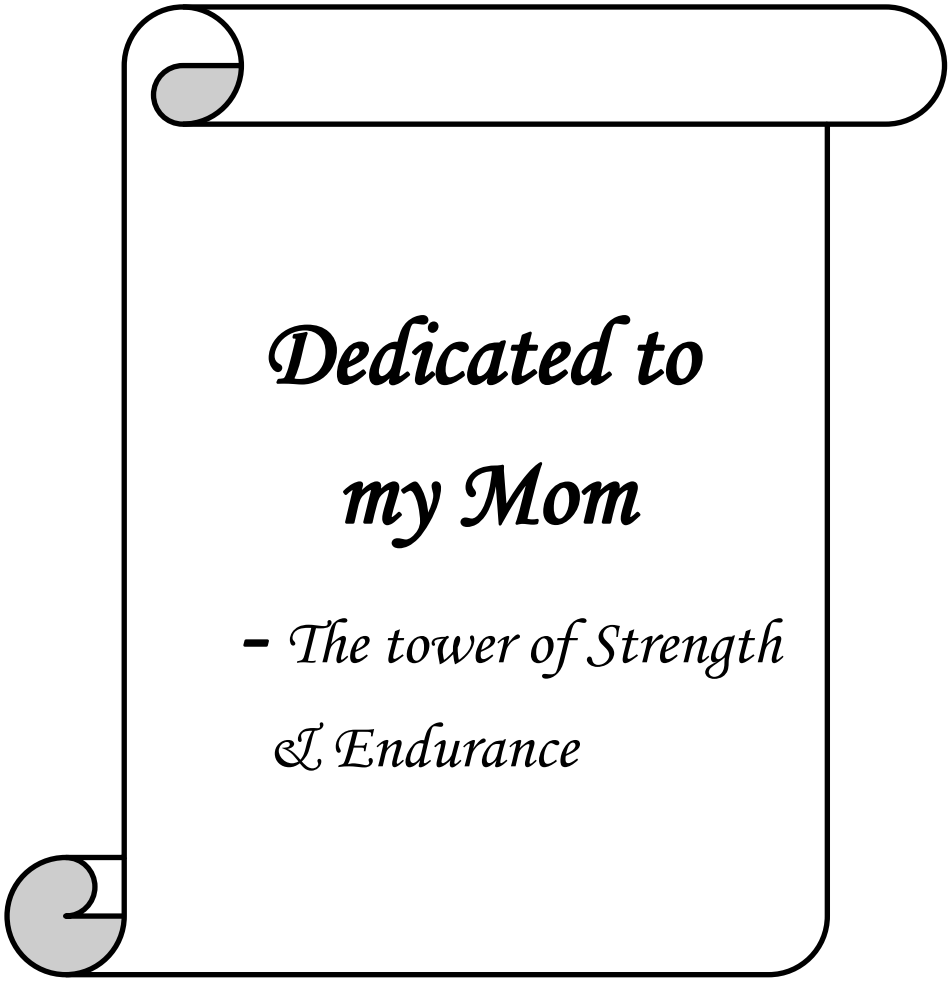
Dedicated to
my Mom
- The tower of Strength
& Endurance

Acknowledgement

Multiple Submissions- "I Can Be Trusted"

"Happiness lies in the joy of achievement and the thrill of creative effort"

-Franklin D. Roosevelt.

The dissertation has been a foundational stone for understanding and learning the process of a research. Completion of dissertation wouldn't be possible without acknowledging the contribution of a list of people.

***Prof S. R. Savithri**, Director, All India Institute of Speech and Hearing! Thank you mam for permitting me to accomplish the study by providing a platform to learn and acquire knowledge.*

*My heartfelt acknowledgement to **Dr. T. Jayakumar** for being a startling mentor and guide. Sir, the completion of my dissertation wouldn't have been successful without your treasured input. Your patience and restful nature have always marvelled me. Thank you sir for not overloading us with the concept of research.*

*My sincere gratitude to **Dr. Vasantha Lakshmi**, for making this invincible statistics into facts and figures. Thank you mam for giving meaning to those numbers.*

*My special thanks to **Dr. Shanty Sebastian**, Consultant Gynaecologist, New life Hospital, Vadapuram for all the timely help you have provided me during my*

data collection. Thank you mam for recommending your patients and affording all possible facilities.

***Dr. Gopi Sankar**, **Reuben Sir** and **Lokesh Sir**, thank you for spending your valuable time in perceptual judging of the samples despite your busy schedules.*

*I extend my gratitude to **Dr. Hameed. C**. Superintendent, Government hospital Nilambur for permitting me to carry out my data collection. Moreover a whole hearted bow to all the expectant mothers for cooperating and participating in my study and making it successful.*

*I have had the privilege to be skilled by the intellects of AIISH and JSS, **Prof. N.P. Nataraja, Dr. K, Yeshoda, Dr. Jayashree C. Shanbal, Dr. R.Rajasudhakar and Dr. S.P. Goswamy.** Thank you to all the faculties, your dedication and professional skills truly have been an inspiration to an aspiring student like me.*

*I would extend my deepest gratitude to the fun filled team NSS! **Dr. Sreeraj Konadath** and **Dr. Prashanth Prabhu** for offering the best time in AIISH. Thank you so much for all the surprises including the final certificate.*

"A happy family is the earliest heaven"

*First and foremost, the reason behind my smile, the cause of my dream, my role model- The lovely lady, my **MoM**…. No word of gratitude can determine my love for you. The best decision maker who always has boundless trust and faith in*

me. Alhamdulillah I couldn't wish for anything better than you in my life ma.. and ***Apa*** *I wish you were still here. Love you to the moon and back…*

Lots of love for my ***Chinna, Nisha dhi, Noushad Aliyaka, Aboochi*** *and my kudoos* ***(Nimshed, Asin, Mehrin, Fellah and little Shellah)*** *for tolerating me and my passions. You have always being so supportive, caring & affectionate though I have always annoyed you with my strange decisions and interests. Thanks a lot & i know you will be always there for me no matter what.*

Cheriyaka, *need a special mention here for providing me unswerving love and care. Thank you for helping me in sorting out all dilemmas.*

Sru, *my mysore gem… no words will be sufficient to express my love for you for being my stress buster & reliever, right from Bachelors to Masters. Hope we gonna be the same however and wherever v are.*

Here comes the 3 greatest gifts of my life, who opened a new perspective about everything in life and I'm the luckiest to call you my pals…

Mr. Thomas Alex, *G… you were always being a constant lifeline throughout my journey. Thanks for giving colors to my shadow. I really needed them…*

Dr. Manoj Kumar K.T, *Man.... you stunned me by being an 'Art of Medicine'. Thanks for all the trust and support you always had in me.*

SI Amruth Rangan, *Probably I wouldn't have overcome my hassles without your goading. Thanks for being an inspirator cum motivator, Amruth.*

*My MYSORE PAcK- **Nayana, Reshli, Pooja**… AIISH life wouldn't have been this sparkling without you guys. Thanks for being my comfort zone. Hostel, outing, hospital, Andaman and list goes on and the ceaseless memories sustain.*

*My special thanks to **Ameena and Shilpa** for all your timely technical and statistical suggestions during the course of my dissertation. Thank you for your troubleshooting ideas every time i was stuck midway.*

*They say a few encounters are decided even before souls are born. I think I know it now. **Achu** and **Papz**, boundless memories in and out Mysore are confined within you. Thank you for showing me different chapters of survival and fortitude.*

Finally but foremost a whole hearted bow to all my friends & classmates for aiding me during my crunch time. Thank you for being with me….

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CHAPTER 1

INTRODUCTION

"Human Voice is the perfect instrument of all but the most difficult to play". It is one of the main tools in human communication and social life which represents what we are. A blend of physiological activities such as respiration, phonation and resonance gives rise to human voice. The human voice which is multidimensional in nature can give rise to various disorders when it is affected (Hakkesteegt, 2009). From the birth cry till puberty the development of human voice is same irrespective of gender. Although both begin to enlarge at puberty, the male larynx outdistances female (Weiss, 1950; Aronson, 1990). As a result the vocal mutation or voice change that takes place as a manifestation of puberty is different in both the genders.

The speech language pathologist (SLP) who also deals with individuals having voice disorders has to identify, assess, diagnose and provide appropriate remedial measures to aid in successful management. The European Laryngeal Society (ELS) recommends the usage of test battery for assessment of voice disorders. It consists of laryngostroboscopy, acoustic analysis, perceptual analysis, aerodynamic measurements as well as subjective self-evaluation of voice (Dejonckere *et al.,* 2001). Voice production is a nonlinear dynamic system, affected by the impairments of the nerves, muscles and vocal organs. The changes in the system can be detected by nonlinear time series analysis tools (Kantz, Holger, & Schreiber, 2004; Little, Max *et al.,* 2009). The professional community of speech pathologist and otolaryngologist are now sensitive to the fact that pathologies in vocal apparatus alone may not be responsible for voice disorders.

Acoustic measures have been regarded as the utmost reliable objective measure of voice quality (Carding, Wilson, MacKenzie, & Deary, 2009). It provides us with quantitative information. It quantifies the degree of severity of dysphonia, monitors the improvement in voice quality with medical and therapeutic management. The acoustic measures including frequency related measures (e.g., fundamental frequency, habitual frequency, frequency range etc.), amplitude related measures (e.g., habitual intensity, extent and fluctuation of intensity etc.), perturbation related measures (e.g., jitter, shimmer etc.) as well as harmonic related measures (e.g., harmonics to noise ratio etc.) have been widely used by researchers (Hirano *et al.,* 1988; Rabinov *et al.,* 1995; Wolfe, Fitch, & Cornell, 1995; Dejonckere & Lebacq, 1996).

Perceptual evaluation, the qualitative measure which is regarded as the gold standard of voice evaluation is widely considered in assessment of voice quality. When an individual's voice doesn't sound normal, patients seek treatment for the voice disorders since the voice quality is perceptual in nature. Similarly the success of treatment is often decided based on whether the voice sounds better or not. But perceptual evaluation is vulnerable to a lot of variations due to several subject-listener factors or task factors. For perceptual ratings to be meaningful, listeners must use scales consistently. Some of the measures that are widely used for perceptual evaluation of voice quality includes Darley Rating System (Darley, Aronson & Brown, 1969) the Grade, Roughness, Breathiness, Asthenia, and Strain (GRBAS) scales (Hirano, 1981), Consensus Auditory Perceptual Evaluation of Voice (CAPE-V) scales (KEMPSTER, Gerrat, Verdolini, Barkmeier-Kraemerv, & Hillman, 2009) and Buffalo Voice Screening Profile (Wilson, 1987). These are frequently used for perceptual evaluation of voice by the voice clinicians (Nemr *et al.*, 2012).

The most used approaches to obtain voice quality are sustained phonations (Baken, Ronald, & Orlikoff, 2000; Philippe *et al.,* 2001; Max *et al.*, 2009; Jafari & Ayyoob, 2013) where patients asked to produce sustained vowels at a comfortable level, hold as long as possible (Max *et al.,* 2009; Jafari & Ayyoob, 2013) and running speech (Philippe *et al.,* 2001; Max *et al.,* 2009; Jafari & Ayyoob, 2013).

Hormonal changes are one of the major factors that can have greater impact on voice across gender over a period of time. The cyclic pattern of Estrogen and progesterone hormone's levels are not the same throughout the life span. Vocal changes related to hormones have been widely studied with reference to menstrual cycle, menopause and pregnancy. Various hormonal disparity can takes place within one menstrual cycle which often lead to thickening of vocal fold epithelial and change in muscle mass. Voice quality is better when estrogen is at its highest and it degrades when estrogen is at lowest level. Reduced vital capacity, reduced vocal intensity, loss of timbre and vocal fatigue can be a consequence of reduced estrogen (Hancock & Gross, 2014).

During pregnancy, in order to develop and adapt the developing foetus the pregnant woman undergoes significant anatomical and physiological adjustments in every system of body (Locktich, 1997). From woman to woman these adjustments vary widely depending on various factors such as pre pregnancy nutrition, genetic determinants of fetal size, and maternal life style (King, 2000). "The normal menstrual cycle disappears, and sex steroid hormone levels are also elevated" (Salturk *et al.,* 2015). These entire alterations can have a subtle impact on subsystems contributing voice production which continue throughout the entire period of pregnancy. E.g., haematological changes, cardiac changes, adaptive anatomical and

physiological changes in renal vasculature, body water metabolism, respiratory changes, adaptive changes in alimentary tract, endocrine changes etc. (Pillay, Piercy, Tolppanen, & Mebazaa, 2016). “Along that mucosa, muscles, bone tissues, cerebral cortex and larynx are directly affected by steroid hormones, estrogen and progesterone” (Cassiraga *et al.,* 2011).

Several recently published studies have reported that voice changes can also be a resultant of hormonal therapy (Lindholm, 1997; Pattie, 1998; Caruso, 2000). “To understand sex hormone’s local effect on the larynx, it is necessary to localize the respective receptors. Hormones like, testosterone and estrogen are dominant factors in determining voice changes throughout the life” (Abitbol *et al.,* 1998). Gender specific alterations take place during puberty. That is, female voice attained at puberty is due to the action of progesterone with an F_0 lesser than that of a child whereas in male androgen is responsible for their vocal frequency lesser than that of child (Abitbol *et al.,* 1999). E.g., Premenstrual vocal Syndrome characterised by decreased range, focal fatigue, loss of timbre and loss of certain harmonics.

Due to hormonal variation, this condition represents with congestion, microvarices, loss of vibratory amplitude and edema in vocal fold (Abitbol *et al.*, 1998). To support the fact that sex hormone has effect on vocal system, another study done Abitbol *et al.* (1998) on menopausal vocal syndrome represented with lowered vocal intensity, inappropriate quality, vocal fatigue, reduced range, deterioration of vocal muscle, reduced mucosal thickness and reduced mobility of cricothyroid joint.

These dramatic differences in hormones during pregnancy bring alterations in various acoustic and perceptual analysis of voice. Pregnancy affects voice parameters by differing perceptual quality and perturbation measures significantly towards the last trimester when fetal demands are greatest (King, 2000). Cassiraga *et al*., (2011) has done a study in final trimester pregnant women and has found abnormal acoustic parameters and perceptual parameters (causing breathiness and hoarseness) in them. During third trimester pregnancy, the breath support is compromised and laryngo-pharyngeal reflux becomes more overt affecting the voice noticeably. As we know estrogen and progesterone level increment during gestation period, it is at its maximum when the women attains the final term Cassiraga *et al*., (2011). Due to this dramatic increment, the impacts of these alterations on vocal attributes are highest during third trimester (Cassiraga, Castellano, Abin, & Izbizky, 2011). "The changes includes hyperaemic and edematous mucosa , vocal fold tissue thickening, sloughing of vocal fold tissues and a raise of basophilic cells (Brodnitz, 1971; Gordon, 2007), reduced respiratory capacity lowers subglottic air pressure which keeps vocal intensity effortful (Colton, 2006), dehydration and an increase of capillary permeability enabling fluids to pass into the interstitial space (Hamdan *et al.*, 2009), changes in breathing/abdominal level and poor respiratory support resulting lowering of Mean Phonation Time (MPT)". Moreover as gestation progresses from first term towards the final term, particularly by the end of second trimester of pregnancy the stomach is displaced to a larger extent elicit gastroesophageal reflux (GER), related to the hoarseness (Bermudez, 2002). Hormonal changes leading to postural changes may even alter the speaking and singing mechanism during pregnancy. As a result, some women may find they can no longer sing, particularly during the third trimester.

During the last four weeks of pregnancy the baby grows rapidly and could gain as much as an additional two pounds (Robertson, 2016). All the above mentioned studies reveal that, comparing first two trimesters human body undergo a dramatic change during the third trimester of pregnancy in which both esophageal dysmotility produced by gestational hormones and progressive abdominal distention resulting from the growing uterus, is particularly high. But there are contradictory studies which question the presence of sex hormone receptors in the vocal fold. One such study done by Schneider *et al*. (2006) to investigate expression of estrogen, progesterone, and androgen receptors in human vocal folds revealed that no specific immunohistochemical staining for the different types of steroid hormones could be observed in either the post-mortem taken biopsies nor the intraoperatively one.

Although the body undergo tremendous changes, in women enduring an uncomplicated pregnancy the alterations resolves post conception with least residual effects (Pillay, Piercy, Tolppanen, & Mebazaa, 2016).

Need for the study

Few studies of vocal changes during pregnancy have been published but none of these investigated perceptual aspects along with objective of vocal characteristics during third trimester of pregnancy, and no published studies on Indian population. There is a possibility that across various populations due to marked changes in human physical and physiological system voice changes during pregnancy also can have alterations. Therefore their voice needs to be evaluated acoustically and perceptually in Indian population. Hence the current study attempts to estimate voice characteristics in third trimester pregnant women in comparison with non-pregnant women.

Aim of the study:

The aim of the study is to analyse the acoustic and perceptual characteristics of voice in third trimester pregnant women and to compare the acoustic voice characteristics of third trimester pregnant women with that of non-pregnant women.

Objectives of the study:

- To estimate the acoustic and perceptual characteristics of voice in third trimester pregnant women.
- To compare the acoustic voice characteristics in non-pregnant and third trimester pregnant women.

CHAPTER 2

REVIEW OF LITERATURE

The vocal instrument comprised of respiratory power source, vibratory body, and oropharyngeal resonating chambers. The larynx is a hormonal target and the voice produced by which is considered as a secondary sex characteristic (Haeseleer *et al.,* 2011). 'The human voice is exquisitely sensitive to changes in the hormonal milieu. It is characterized by its frequency, intensity and harmonics. The harmonics are hormonally dependent" (Abitbol, 1999). Due to anatomical and physiological changes that take place during puberty, differentiation of human larynx causing voice changes are evident during and even after puberty. Structural and functional variations in different genders, as in females-shorter vocal cords, lesser vital capacity, lesser transverse and sagittal infraglottic diameters in comparison with males often results in changes in acoustic and perceptual parameters of voice (Saltark *et al*., 2015). Previous studies have found a significant correlation between the changes that both cervic and vocal fold smears undergo during menstrual cycle, demonstrating a relevant hormonal influence on laryngeal tissues. It can be hypothesised that such tissue changes that may occur during pregnancy affect conditions for phonation with respect to e.g. Vocal fold motility (Sundberg, Johan, 2009).

Larynx, a hormone dependent organ

In the late 1980s, Sataloff was one of the otolaryngologists to explore hormonal effects on the human voice. In the article -Hormones and the Voice, he explained how vocal response related to thyroid levels and sex hormones, by noting that many voice dysfunctions are the results of changes in the fluid content in the

lamina propria, which is located just beneath the laryngeal mucosa of the vocal folds. Mortola (1992) have found that hormonal mutations cause variations in the bulk and shape of the vocal folds, causing a change in voice quality. The voice quality is endangered by external factors, such as cyclic variations in sexual hormones.

According to Abitbol (1999) hormones are the mediators in the relationship between our brain and organs, including the larynx (Fraser *et al.*, 2015). The most complex hormonal system is found in the human species. If the delicate balance of hormones are disrupted, the resulting damage could be irreversible since the voice quality is influenced by hormonal changes. (Brodnitz & Friedrich, 1971; Brunings *et al.*, 2013) explored that estrogen receptors and progesterone receptors are expressed in the larynx of the female human vocal fold in concurrent with edema. While focusing the sound quality of the voice the hormonal environment and human body are two independent terms which is to be considered. Depending on the environment the anatomy of vocal apparatus changes in which the inside environment consists of hormones that control bodily function. Therefore it is important to be familiar with the hormones existing in a human body that have influence on laryngeal system too. The laryngeal system is externally responsive to sex hormones- androgen estrogen and progesterone. Through bloodstream hormones reaches every system of body and the influence hormones have on all bodily function is powerful.

"In both males and females, the voice evolves from childhood to senescence under varied levels of estrogen, progesterone, and androgens" (Abitbol *et al.*, 1999). Few studies have proved that hormonal treatments too have impact on an individual's voice. A study done by (Hamdan *et al.*, 2007) analysed changes in vocal symptoms

in relation to estrogen level in 31 women undergoing in vitro fertilization. Vocal symptoms including vocal tiring or fatigue, vocal straining, throat clearing, lump sensation, hoarseness, and aphonia were evaluated. The result revealed that the most common vocal symptom in all visits was throat clearing, with an incidence of 22.6% in first and second visits and 19.4% in the third visit. They also found subjects with vocal symptoms had lower estradiol (a major oestrogen produced in the ovaries) level compared with those with no vocal symptoms. In another study done by Amir, Jacob and Harari, 2013 examined the effect of In Vitro Fertilization (IVF) treatment on acoustic properties of women's voice in three successive sessions, before, during and after the treatment. The study was conducted based on the hypothesis that in IVF treatment, women are exposed to substantially higher levels of estrogen compared with women experiencing natural hormonal cycle. The result revealed a significant reduction in two F_0 measures and in two perturbation measures throughout the treatment. Before treatment, a negative correlation was found between F_0 and estrogen levels. After treatment, however, a negative correlation was found between F_0 and endometrial thickness which is suggestive of an association between IVF treatment and specific voice properties. Depending on elevated hormonal levels voice characteristics differ in each gender as well as in each individual (Hancock & Gross, 2014).

Females mature in response to increased amounts of progesterone and estrogen. The presence of estrogen induces hypertrophy (an increase in volume) and proliferation (an increase in tissue cells) which causes thickening of the mucous membrane of the vocal folds, resulting greater vibratory amplitude and an improvement in sound timbre (Clevel & Clinic, 2015). When ovaries secrete estrogen, it resulted in slight thickening of cordal mucous membrane. It can cause

high vibratory amplitude. “The desquamation of the superficial cells are reduced together with the amount of laryngeal mucus” (Hamdan *et al.,* 2007). “Estrogen increases the oxygenation of the vocal folds and improves the permeability of blood vessels and capillaries in the vocal folds” (Cherney & Kristeen, 2016). Another important function of estrogen is to prepare the tissue that enables progesterone to be effective (Khare, 2016). On the other hand, progesterone causes cells on the surface of the vocal mucous membrane to slough off, that is, enhance desquamation” (Hamdan *et al.,* 2007). Progesterone thickens the secretions of glands both above and below the vocal folds and similar to estrogen causes the shedding of surface cells of the vocal folds. It promotes sloughing of the laryngeal epithelium and works against proliferation. It also makes the glandular secretions more viscous, leading to a decrease in vibratory efficiency and possibly increased cell damage (Anderson, Anderson, & Sataloff, 1996; Rubin, Sataloff, & Korovin, 1996). Changes in oestrogen and progesterone levels also influence the structural alterations in the gastrointestinal tract. These include abnormalities in gastric neural activity and smooth muscle function, leading to gastric dysrhythmia or gastroparesis. The alterations are pronounced in women with pre-existing gastrointestinal diseases such as gastroesophageal reflux disease, diabetic gastroparesis, gastric bypass surgery or inflammatory bowel disease (Koch, 1997; Clark, Costantine, & Hankins, 2012). Unlike estrogen, progesterone secretions may cause an imbalance in the distribution of interstitial fluid, the fluid found in spaces between tissue cells, resulting in swelling of the vocal folds (Khare, 2016). When these hormones are out of balance, there is asymmetry in vocal fold vibration, which causes irregularity in their oscillatory patterns (Depypere, 2013).

Underproduction of thyroid hormone can cause deepening of voice. This is suspected due to thickening of vocal folds as a result of mucopolysaccharide deposition which reduces F_0 of the vocal folds. Thyroid hormones are also known to cause voice disturbances.

In normal physiology, the hypothalamus releases a thyrotropin-releasing hormone (TRH), a molecule that stimulates the anterior pituitary gland to release a thyroid-stimulating hormone. The TSH in turn stimulates the thyroid gland to produce T4 and T3, of which T3 is the more biologically active hormone. Thyroid hormones serve to increase the rate of metabolic functions in the body. When patients have hypothyroidism (low thyroid function), hoarseness and loss of range are common complaints. The mechanism is not known for certain, but it is believed to be related to increased levels of polysaccharides in the vocal folds, leading to increased fluid retention and vocal fold thickening (Ritter, 1964). A woman's voice always develops masculine characteristics after an injection of testosterone and such a change is irreversible.

In nonpregnant women, the lipid cells under the cordal mucous membrane are stimulated during the maturation phase of the menstrual cycle, this in turn results in a more supple voice with a good timbre.

Voice in Pregnancy

From the above literature it is evident that human voice and vocal apparatus is susceptible to hormonal changes throughout the life. We have clear evidence of drastic changes in sex hormones takes place during puberty, menstruation, menopause and other hormonal syndromes (Abitbol *et al.*, 1998). Similarly pregnancy is a period that requires major anatomic, physiologic, psychologic and metabolic adjustments

begins with conception and ends in the postpartum period. Pregnancy is a state that can exhibit dramatic changes in hormonal as well as immunological system of the individual (Hamdan *et al.*, 2007).

Women experience swelling in several parts of their body during pregnancy due to fluid retention, blood vessel dilation, hormonal increment as well as other metabolic alterations. These can cause change in human body including vocal system. These alterations include postural changes, swelling of vocal cord and altered range of voice, reduced lung capacity, lowered nasal resonance, increased likelihood of acid reflux etc. The changes can cause a noticeable difference in voice quality. The changes are observed even in bodily tissues. For example, cervix undergoes deep structural/biomechanical alterations due to an increase in concentration of progesterone and it can be hypothesised that such tissue changes that may occur during pregnancy affect conditions for phonation (Sundberg & Johan, 2009). Similarly estrogen also improves the permeability of the blood vessels and capillaries on the vocal folds in an attempt to increase oxygenation. This can explain the well-rounded voice described early in gestation. Through an understanding of these mechanisms, studies and evidences can be optimized to allow individuals to maintain their normal voice use. With respect to the configuration of the thoracic cage that do occur during pregnancy leads to mechanical/ anatomic changes and the effect is much earlier than the mechanical pressure from the enlarging uterus. These anatomical changes include increase in the sub costal angle from 68° to 103°, expansion of the chest diameter by 2 cm and the circumference of the chest by 5-7 cm. The level of diaphragm rises by 4 cm with progression of gestation. It increases the diaphragmatic excursion by 1-2 cm. These mechanical changes lead to a decrease in the functional residual capacity (FRC), expiratory reserve volume (ERV), residual volume (RV),

and total lung capacity (TLC). On the other hand these changes keep the maximum inspiratory and expiratory pressures unchanged (Thompson & Cohen, 1938, Weinberger & Weiss, 1980; Gilroy & Mangura, 1988). During pregnancy, there is a large increase in water content in the body for the maternal water metabolism. By the end of conception the total body water increases by 6.5–8.5 L. Therefore the effects of pregnancy in overall bodily functions have enormous evidence.

Robertson (2016) opined that Hormonal changes during pregnancy cause relaxation of lower esophageal sphincter, which usually prevents stomach acids from splashing up into the esophagus. Furthermore, the stomach capacity is reduced which means acid regurgitation is more likely when the pregnant women's stomach enlarges. Symptoms of acid reflux causing laryngeal irritation include an altered voice, heart burn, frequent throat clearing and an altered voice.

Comparing to first two trimesters, in 3rd trimester they even experience a tremendous differences such as increase in their weight, postural changes that evidently alter the support and breathing mechanism. During the period the susceptibility to haemorrhaging is high due to the dilation of blood vessels in vocal cords. The voice is susceptible to elevated levels of sex steroid hormones during pregnancy, especially during the last trimester when estrogen and progesterone are higher than normal, with progesterone being the dominant hormone (Khare, 2016). Therefore some women may find it difficult to raise their pitch and often can no longer speak continuously, particularly in the third trimester (Robertson, 2016). These are the reason why pregnant women are advised to take vocal rest during pregnancy. Physiologically, the transformation of girl's voices is due to the hormonal levels

of estrogen and progesterone (Hancock, 2014). Laryngopathia gravidarum, a rare complication seen during pregnancy may be a severe or less severe condition that relates to changes in the voice, such as hoarseness, which Sataloff in 1987 describes as being similar to those changes experienced during menstruation. He concludes that some of the vocal changes during pregnancy may even be thought of as desirable.

Variation in vocal attributes witnessed during the third trimester of pregnancy need to be investigated in correlation with respiratory, metabolic and hormonal changes. Thompson and Cohen (1938) observed changes with respect upper and lower respiratory tract which in turn changes lung capacity, in which the mucosa of nasopharynx and nasal cavity becomes hyperemic and edematous with hypersecretion of mucous leading to nasal congestion.

Ellegard *et al.* (2000) investigated the cumulative incidence of pregnancy induced rhinitis with smokers. The study found that, pregnant women who smoke are more likely to be mouth breathers due to strain on phonatory apparatus and reduced efficiency. Mouth breathing leads to an increase in the phonatory threshold pressure and the phonatory effort by drying the superficial mucosa of the vocal fold (Sivasankar & Fisher, 2002).

Cassiraga, Castellano, Abasolo, Abin, & Izbizky (2011) compared voice attributes between 44 third trimester pregnant and 45 nonpregnant matched women of 20-40 years by analysing and comparing values of fundamental frequency, maximum phonation time, vocal intensity, perturbation rates, and physical acoustic qualities. They a l s o underwent an auditory- perceptual evaluation of voice quality according to RASAT scale—hoarseness (R), asthenia (A), breathiness (S), roughness (A), and

strain (T). Results revealed that no differences in the acoustic analysis with regard to F_0, isolated vowel intensity, and perturbation rates but most pregnant women showed abnormal parameters of auditory perceptual evaluation, a higher incidence of gastroesophageal reflux, predominance of clavicular breathing, and a reduction of phonation time. Breathiness, hoarseness and combination of both were observed in 14, 5 and 7 women respectively. By interpreting the results, experimenters stated that differences found in both groups are suggestive of physiologic and body changes produced during pregnancy affect voice quality.

Hancock and Gross (2014) hypothesised that spectral and aerodynamic measures would be more sensitive to tissue-level changes caused by pregnancy hormones. They considered a longitudinal study of a 32-year-old woman's pregnancy. Weekly voice samples were analysed for obtaining acoustic (fundamental frequency, perturbation ratios of shimmer and jitter, Harmonic-to-Noise Ratio, spectral measures, and maximum phonation time) and aerodynamic (average airflow, peak flow, open quotient, and speed quotient) parameters. All measures appeared generally stable during weeks 11–39 of pregnancy compared with 21 weeks postpartum. Slight decrease in minimum airflow and open speed quotient may reflect suspected vocal fold tissue changes. The study recommended that future studies need to monitor and test correlations among hormone levels, visual analyses of vocal fold mucosa, aerodynamic function, and glottal efficiency.

A longitudinal study conducted by Sundberg (2012) in a 28-year-old classically trained soprano singer during her last trimester of pregnancy and for 11 weeks after the birth of her child showed an increase in phonatory threshold pressure and collision threshold pressure during the last trimester and it was associated with

elevated estrogen and progesterone hormones. The elevated hormonal level indicates an increase in vocal fold epithelium thickness and tissue viscosity. These changes may not be same in a non-singer as the birth approaches.

In a comparison study done by Cassiraga *et al.* (2012) among 44 third-trimester pregnant women and 45 nonpregnant controls, the pregnant women experienced more breathiness and hoarseness, shorter maximum phonation time (MPT), and an increase in speech intensity. Hamdan *et al*. (2007) explored the effect of pregnancy on speaking voice by comparing the vocal symptoms such as hoarseness, vocal fatigue, and aphonia and acoustic analysis including fundamental frequency (F_0), habitual pitch, relative average perturbation (RAP), shimmer, noise-to-harmony ratio (NHR), and maximum phonation time (MPT) in 25 pregnant women pre- and post-partum with 21 non pregnant controls. Investigators found no significant differences in the incidence of vocal symptoms in pregnant women versus controls except for vocal fatigue (12%) which was more prevalent in the pregnant group. In terms of acoustic analysis though there was a significant decrease in MPT rest of the variables were comparable with controls. They also found in Postpartum, the MPT and F_0 significantly increased and a significant decrease in the voice turbulence index (VTI). During the study they could also observe the behavioral variations in subjects due to the altered maternal physiology that is close to half of the subjects have reported history of phonotraumtaic behavior and gastroesophageal reflux disease, impaired breathing support, pregnancy induced rhinitis during the last trimester.

Salturk *et al.* (2015) evaluated vocal changes in pregnancy according to trimesters both objectively and subjectively by recruiting 50 pregnant women and 15 non pregnant women as the subjects. Out of 50 pregnant women, 18, 17, and 15 of

them were in their first, second and third trimester respectively. Voices were recorded using an AKG D5 dynamic microphone. During acoustic analysis fundamental frequency (F_0), jitter, shimmer, noise-to-harmonics ratio (NHR), and minimum and maximum pitch were determined by using PRAAT software. Subjective analysis was done by Voice Handicap Index 10 (VHI-10). Along this, Laryngologic examination was evaluated via reflux finding score (RFS). In results significantly varied parameters were Maximum phonation time (MPT), VHI-10, and RFS. That is MPT reduced in third trimester, RFS was deteriorated in first and third trimesters higher erythema/hyperemia score in first and third trimester groups, and VHI-10 scores were higher in third trimester. But in acoustic analysis no parameters other than MPT showed any significant variation in any group.

Pregnant women need to be aware of these issues and should not hesitate to consult voice pathologist for evaluation when voice problems are suspected. Without knowledge about the potential effects of hormonal fluctuations on the female voice, gynaecologists and pregnant women may not be able to identify symptoms that could be linked to a hormonal event and may not seek appropriate treatment when needed. Some vocal symptoms may even be misdiagnosed by a physician. Understanding how the female voice responds to hormonal changes during phases of life is imperative for pregnant women, because this knowledge results in better management of challenging vocal issues due to hormonal events. Most gynaecologists are not proficient in managing, or even identifying, the subtle hormonal issues that affect the voices of pregnant women. Along with voice pathologist, other health care professionals needs to be educated on the prevention, assessment and management of disorders and discomfort specific to voice during pregnancy. It is problematic that the voices of pregnant women are affected by their hormones, particularly as most do not have an

adequate understanding of how and why. There is also is a lack of readily available, reliable information on voice characteristics in pregnancy especially in south Indian context.

It is mandatory to have a thorough understanding of various effects of pregnancy for professionals dealing with the same. The information and evidence providing through the study can serve as a guide for understanding the influence and impact of sex hormones on the female voice during 3rd trimester pregnancy.

CHAPTER 3

METHOD

Present study was carried out to estimate the acoustic and perceptual characteristics of voice in third trimester pregnant women and to compare the acoustic voice characteristics in pregnant and non-pregnant women. The methodologies adopted were as follows:

Participants

A total of 60 individuals were enrolled for the study in which, Group I consisted of 30 women in third trimester of pregnancy and Group II consisted of 30 non pregnant women with normal voice quality. All the participants were within the age range of 20-40 years were native Malayalam speakers (mean age of 26.99 years). Age matched participants were considered in both groups. Group I which consisted of pregnant women in third trimester pregnancy who were recommended by gynaecologist and group II, non pregnant women who were selected after ensuring they are fit for performing the task with no other medical issues. Background information regarding medical history was collected.

Inclusion criteria for group I & II

- Participants were native speakers of Malayalam
- Participants of group I should have normal quality of voice as judged by a Speech Language Pathologist.

Exclusion criteria for group I & II

- Women, who had history of dysphonia, laryngologic disease, acute or chronic inflammatory processes, laryngeal surgery or pathology, head and neck radiotherapy, smoking, other hormonal issues such as polycystic ovarian disease, thyroid disorders, fibroid and are undergoing treatment for the same were not considered in the study for both group I and II.
- Pregnancy through IVF (In vitro fertilisation) was excluded from the group I.

Stimuli

The two groups, the pregnant women in third trimester and non-pregnant women were asked to perform 2 different tasks.

- **Phonation of vowels:** The vowels /a/, /i/, /u/ were considered for the phonation. Then samples of sustained phonation were collected by asking the subjects to phonate as long as possible in their comfortable loudness, followed by a deep inspiration.
- **Sentences:** A meaningful Malayalam standard passage (Savithri & Jayaram, 2005) was considered for reading task.

Procedure

Before recording, the participants were explained of the procedure and rationale behind recording. Then an informed consent was taken. They were asked to sit straight in a relaxed manner. The recordings were obtained in a quiet room using directional microphone with a frequency of 44.1 KHz which is kept at a distance of 15cm from the lips of the participant to avoid breathing noise. Olympus LS-100 digital voice recorder was used to record the voice. Same recording settings were used for the recording of both sustained vowel and reading samples. Followed by deep

inspiration, the participants were asked for the sustained phonation of vowels /a/, /i/ and /u/ and reading sample. Among 3 trials of sustained vowel the best trial was considered for analysis.

Analysis

The recorded samples will be subjected to acoustic and perceptual analysis.

Acoustic Analysis

The obtained audio recordings were subjected to objective analysis using Multi-Dimensional Voice Profile (MDVP) software Kay Elemetrics, NJ. Prior to it that stable middle portion of 3 vowels /a/, /i/, /u/ were extracted by using PRAAT software. The extracted samples in .wav format were renamed. Later the selected samples were analysed by using MDVP software. From the output of MDVP, the following parameters will be considered for analysis.

- ✓ Average Fundamental Frequency (Mean F_0)
- ✓ Standard Deviation of F_0 (SDF_0)
- ✓ F0-Tremor Frequency (FFTR)
- ✓ Amplitude tremor Frequency (FATR)
- ✓ Jitter Percent (JITT)
- ✓ Relative Average Perturbation (RAP)
- ✓ Fundamental Frequency Variation (VF_0)
- ✓ Shimmer Percent (SHIM)
- ✓ Amplitude Perturbation Quotient (APQ)
- ✓ Noise to Harmonic Ratio (NHR)
- ✓ Voice Turbulence Index (VTI)
- ✓ F0-Tremor Intensity Index (FTRI)
- ✓ Amplitude tremor Intensity Index (ATRI)

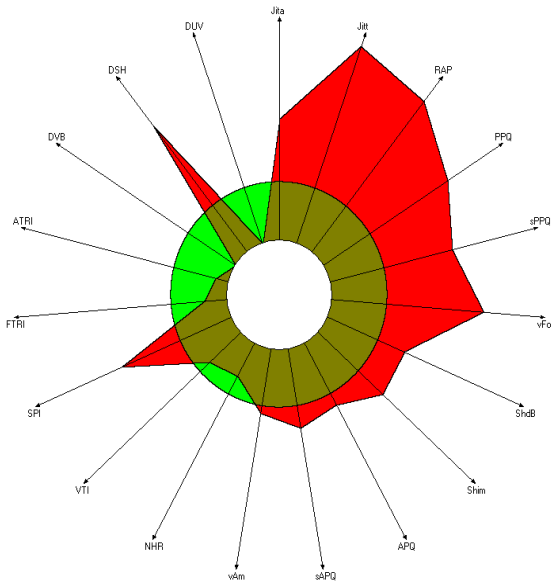


Figure 3.1: Example of graphical output obtained for vowel /a/ for a third trimester pregnant woman from MDVP software.

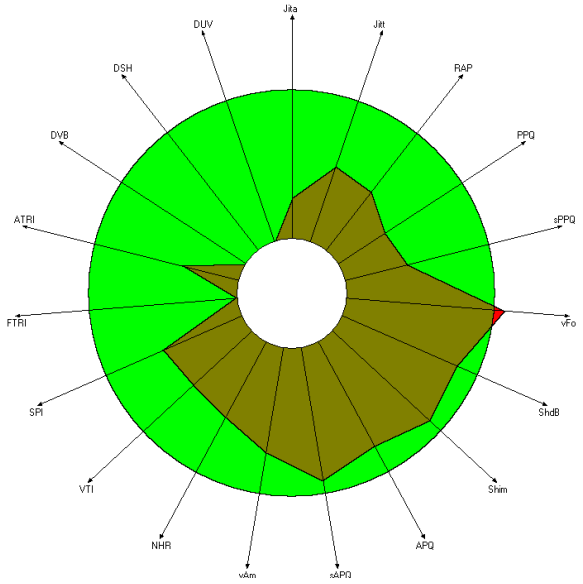


Figure 3.2: Example of graphical output obtained for vowel /a/ for a non-pregnant woman from MDVP software.

Perceptual Analysis

The same samples of sustained phonation and reading sample of maximum 1 minute were used for perceptual analysis. Three experienced speech language pathologists were served as judges for perceptual evaluation. The judges had a minimum of four years of experience in voice assessment and management following their completion of Post Graduate degree in Speech-Language Pathology and are currently involved in clinical practice with voice disorders. All the judges were blindfolded regarding the identity and details of the individuals from whom samples were obtained. The voice samples were presented randomly through the headphones in a quiet environment. They were asked to rate the quality of voice based on a four point rating scale (0- normal, 1- slight, 2- moderate, 3- severe)of the G(grade), R(rough), B(breathy), A(asthenia) and S(strain) - GRBAS scale. The average rating

of three SLPs will be considered. Same procedure was carried out for both the group of participants.

Once the MDVP scores and perceptual analysis scores were obtained, they were tabulated and subjected to appropriate statistical analysis using Statistical Package for Social Sciences (SPSS) version 20.0.

Statistical Analysis

The obtained MDVP values for the participants of both groups along with perceptual measures on GRBAS scale as rated by the judges were subjected to statistical analysis using SPSS (Version 20.0), in order to derive:

- ✓ Normality of the sample was studied using Shapiro-Wilk's test.
- ✓ Descriptive statistics to obtain mean median and standard deviation for /a/, /i/ and /u/ for both the groups.
- ✓ Since the data did not follow normal distribution, Mann- Whitney U test was administered to compare the acoustic voice characteristics in third trimester pregnant and non-pregnant women.
- ✓ Kappa co-efficient was used to obtain inter- judge reliability for the perceptual evaluation of the third trimester pregnant women.

CHAPTER 4

RESULTS

Present study focused to estimate acoustic and perceptual characteristics of voice in third trimester pregnant women and to compare the acoustic voice characteristics in pregnant and non-pregnant women. The results of this study will be discussed under the following headings:

- ✓ Normality of the sample was studied using Shapiro-Wilk's test.
- ✓ Mean Median and Standard deviation of voice parameters for vowel /a/, /i/, /u/ for final trimester pregnant women and non-pregnant women.
- ✓ Comparison of acoustic parameters for pregnant and non-pregnant women.
- ✓ Kappa co-efficient for inter- judge reliability & Mean, SD, and Median for the perceptual evaluation of the third trimester pregnant women.

Normality check for the data

In order to determine the normality of the sample selected for the study, Shapiro Wilk's test of normality was carried out. It revealed that many parameters did not follow normal distribution with p values higher than 0.05. Since the normality principle was violated an attempt was made to remove outliers but even after removal of some outliers, the data did not follow normal distribution as witnessed from the results of Shapiro Wilk's test. Hence non-parametric test (Mann- Whitney U test) was administered to compare the acoustic voice characteristics in non-pregnant and third trimester pregnant women. Table 4.1 indicates the test of normality for both the groups for vowels /a/, /i/, /u/ by using Shapiro-Wilk's Test.

Table 4.1:

Test of Normality

Group I						
Parameters	**/a/**		**/i/**		**/u/**	
	Stat	**P-value**	**Stat**	**P-value**	**Stat**	**P-value**
MF_0	0.912	0.004	0.957	0.134	0.747	0.000
SDF_0	0.907	0.003	0.945	0.053	0.611	0.000
JITT	0.951	0.079	0.945	0.051	0.699	0.000
RAP	0.955	0.110	0.945	0.051	0.691	0.000
VF_0	0.924	0.010	0.096	0.188	0.655	0.000
SHIM	0.867	0.000	0.980	0.637	0.824	0.000
APQ	0.859	0.000	0.986	0.904	0.839	0.000
NHR	0.946	0.053	0.946	0.053	0.571	0.000
VTI	0.987	0.920	0.964	0.236	0.892	0.001
FFTR	0.812	0.001	0.694	0.000	0.772	0.000
FATR	0.935	0.153	0.877	0.010	0.781	0.000
FTRI	0.790	0.000	0.931	0.131	0.531	0.000
ATRI	0.944	0.235	0.860	0.005	0.948	0.291
Group II						
Parameters	**/a/**		**/i/**		**/u/**	
	Stat	**P-value**	**Stat**	**P-value**	**Stat**	**P-value**
MF_0	0.982	0.792	0.955	0.131	0.957	0.148
SDF_0	0.841	0.000	0.910	0.005	0.961	0.204
JITT	0.809	0.000	0.710	0.000	0.932	0.023
RAP	0.819	0.000	0.719	0.000	0.933	0.024
VF_0	0.817	0.000	0.862	0.000	0.962	0.220
SHIM	0.946	0.065	0.725	0.000	0.922	0.011
APQ	0.935	0.028	0.762	0.000	0.927	0.016
NHR	0.940	0.042	0.946	0.066	0.919	0.009
VTI	0.934	0.027	0.906	0.004	0.915	0.007
FFTR	0.801	0.104	0.764	0.051	0.746	0.035
FATR	0.674	0.005	0.733	0.026	0.759	0.047
FTRI	0.642	0.002	0.640	0.002	0.879	0.334
ATRI	0.736	0.028	0.840	0.195	0.945	0.683

#(a).MF_0- Mean fundamental frequency; (b).SDF_0- Standard Deviation of Fundamental frequency; (c). FFTR- F_0 Tremor Frequency; (d). FATR-Amplitude Tremor Frequency; (e). JITT-Jitter Percent; (f). RAP-Relative Average Perturbation; (g). VF_0-Fundamental Frequency variation; (h). SHIM-Shimmer Percent; (i). APQ-Amplitude perturbation Quotient; (j). NHR- Noise to harmonic Ratio; (k). VTI-Voice Turbulence Index; (l). FTRI- F_0 Tremor Intensity Index; (m). ATRI- Amplitude Tremor Intensity Index.

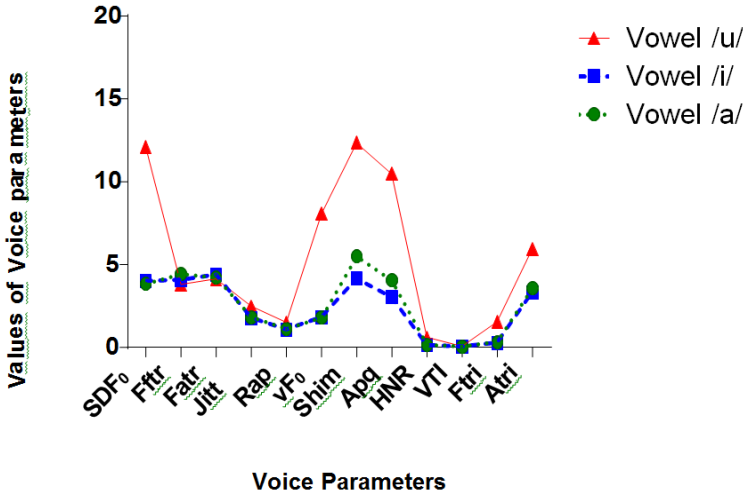
Mean, Median and Standard deviation for vowel /a/, /i/, /u/ for third trimester pregnant women and non-pregnant women

Descriptive statistics was carried out to obtain mean, median, Standard deviation for vowel /a/, /i/and /u/ for both the groups. Table 4.2 indicates the mean, standard deviation and median for vowel /a/, /i/, and /u/ of Group I. Table 4.3 indicates the mean, median and standard deviation of for vowel /a/, /i/ and /u/ of Group II.

Table 4.2

Descriptive statistics of voice parameters for vowel /a/, /i/, and /u/ of Group I (3rd trimester pregnant women)

	Group I								
	Vowel /a/			**Vowel /i/**			**Vowel /u/**		
	M	**SD**	**Med**	**M**	**SD**	**Med**	**M**	**SD**	**Med**
MF_0	210.5	23.26	215.6	218.1	19.56	218.6	233.8	45.59	223.7
SDF_0	3.849	1.974	3.691	4.005	1.442	4.205	12.09	36.31	3.706
FFTR	4.437	2.332	3.943	4.079	2.353	3.361	3.785	1.452	3.320
FATR	4.217	1.578	4.167	4.393	1.910	3.738	4.128	1.842	3.520
JITT	1.831	1.095	1.790	1.780	0.910	1.568	2.477	2.437	1.373
RAP	1.111	0.664	1.085	1.067	0.541	0.937	1.499	1.506	0.844
VF_0	1.798	0.848	1.703	1.825	0.621	1.920	8.051	11.79	1.656
SHIM	5.500	2.193	5.148	4.145	1.139	4.300	12.33	10.95	7.096
APQ	4.041	1.652	3.714	3.020	0.810	3.077	10.46	9.244	6.912
NHR	0.143	0.030	0.139	0.132	0.026	0.136	0.595	0.950	0.168
VTI	0.039	0.014	0.042	0.039	0.016	0.038	0.035	0.019	0.034
FTRI	0.323	0.244	0.260	0.279	0.201	0.248	1.527	2.644	0.320
ATRI	3.572	2.118	3.088	3.331	1.956	3.089	5.930	3.418	5.361



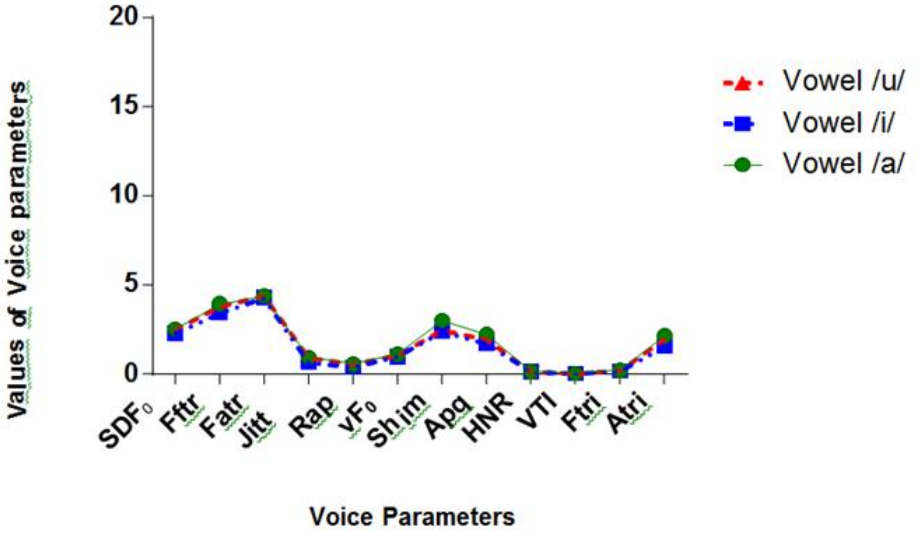
Graph 4.1: Mean value of voice parameters of pregnant women across vowels /a/, /i/ and /u/.

The above graph indicates greater increment in vowel /u/ in comparison to vowels /a/ and /i/ majorly in parameters such as SDF_0, VF_0, Shimmer, APQ, and ATRI.

Table 4.3:

Descriptive statistics of voice parameters for vowel /a/, /i/, and /u/ of Group II (non-pregnant women)

	Group II								
	Vowel /a/			**Vowel /i/**			**Vowel /u/**		
	M	**SD**	**Med**	**M**	**SD**	**Med**	**M**	**SD**	**Med**
MF_0	225.6	20.16	225.4	234.5	21.03	234.0	239.51	26.37	238.3
SDF_0	2.547	1.052	2.289	2.280	0.9372	2.014	2.4995	0.716	2.556
FFTR	3.937	1.926	3.572	3.430	2.317	2.914	3.7902	1.187	3.509
FATR	4.412	1.928	3.810	4.291	1.964	3.653	4.4307	2.688	3.704
JITT	0.945	0.675	0.725	0.657	0.589	0.449	0.926	0.467	0.837
RAP	0.569	0.405	0.437	0.395	0.355	0.267	0.560	0.284	0.504
VF_0	1.131	0.462	0.920	0.985	0.441	0.860	1.052	0.312	1.049
SHIM	3.012	0.926	3.018	2.399	1.190	2.162	2.476	1.172	2.418
APQ	2.219	0.703	2.193	1.703	0.769	1.513	1.948	0.934	2.001
NHR	0.125	0.016	0.123	0.133	0.026	0.138	0.123	0.040	0.132
VTI	0.042	0.010	0.044	0.043	0.015	0.041	0.026	0.012	0.029
FTRI	0.203	0.140	.1725	0.175	0.232	.1340	0.192	0.109	0.178
ATRI	2.161	1.406	1.7380	1.578	0.943	1.3500	1.992	1.197	1.781



Graph 4.2: Mean value of voice parameters of non-pregnant women across vowel /a/, /i/ and /u/.

In above graph, no significant variation is found between the vowels /a/, /i/ and /u/. But while comparing both the tables the Standard Deviation was very high in group I in several parameters.

Comparison of acoustic voice characteristics between the third trimester pregnant women and non-pregnant women

Mann- Whitney U test was employed to compare the difference between voice parameters in third trimester pregnant women and non-pregnant women. Table 4.4 indicates the z values for the comparison between group I & Group II using Mann Whitney U test.

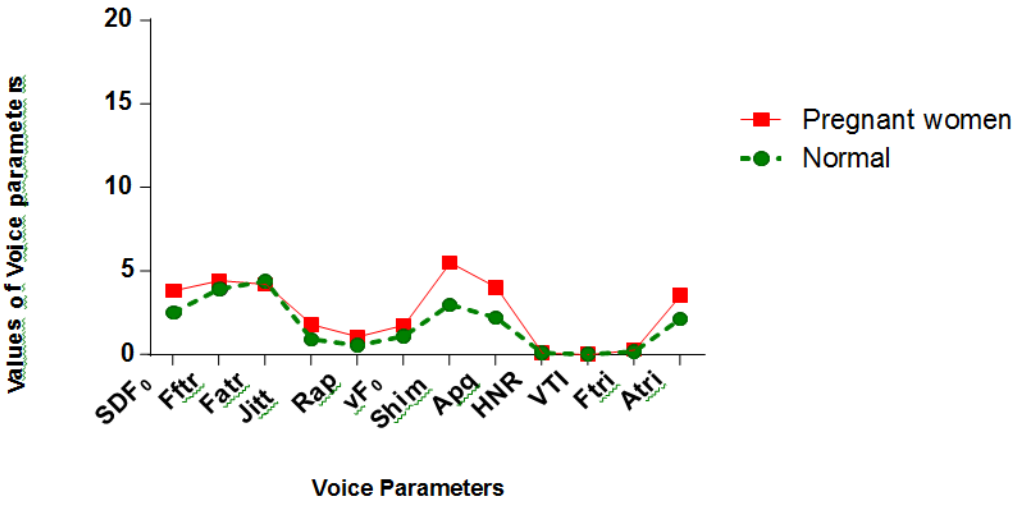
Table 4.4

Z-value and P-value of Mann Whitney U test for the comparison of voice parameters across 3rd trimester pregnant and non-pregnant women.

	/a/		/i/		/u/	
	Z	**P-value**	**Z**	**p-value**	**Z**	**p-value**
MF_0	-2.529	0.011**	-2.769	0.006**	-1.910	0.054*
SDF_0	-3.119	0.002**	-5.089	0.000**	-4.459	0.000*
FFTR	-0.505	0.613	-1.356	0.175	-0.290	0.772
FATR	-0.230	0.818	-0.340	0.734	-0.298	0.766
JITT	-3.859	0.000**	-5.524	0.000**	-4.529	0.000**
RAP	-3.849	0.000**	-5.479	0.000**	-4.484	0.000**
VF_0	-3.914	0.000**	-5.638	0.000**	-4.869	0.000**
SHIM	-5.898	0.000**	-5.868	0.000**	-6.110	0.000**
APQ	-5.878	0.000**	-6.038	0.000**	-5.939	0.000**
NHR	-2.655	0.008**	-0.090	0.928	-4.345	0.000**
VTI	-1.015	0.310	-1.030	0.303	-1.866	0.062
FTRI	-2.094	0.036*	-2.961	0.003**	-3.357	0.001**
ATRI	-3.586	0.000**	-4.617	0.000**	-5.099	0.000**

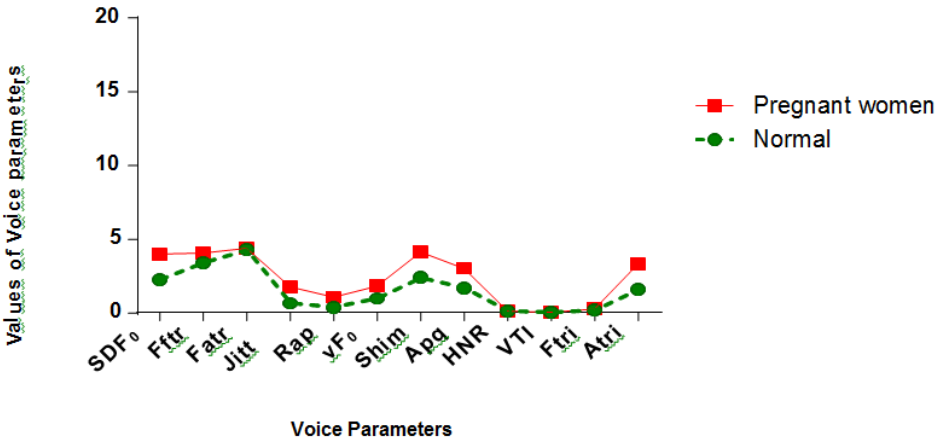
** p<0.05, ** p<0.01*

The above table shows significant difference in all parameters except FFTR, FATR and VTI. Fundamental frequency and standard deviation of F_0 showed significant difference between pregnant and non-pregnant women for all vowels. The result also indicates that all pregnant women had significant difference in perturbation measures such as JITT, RAP, VF_0, SHM, APQ and tremor measures such as FTRI and ATRI.



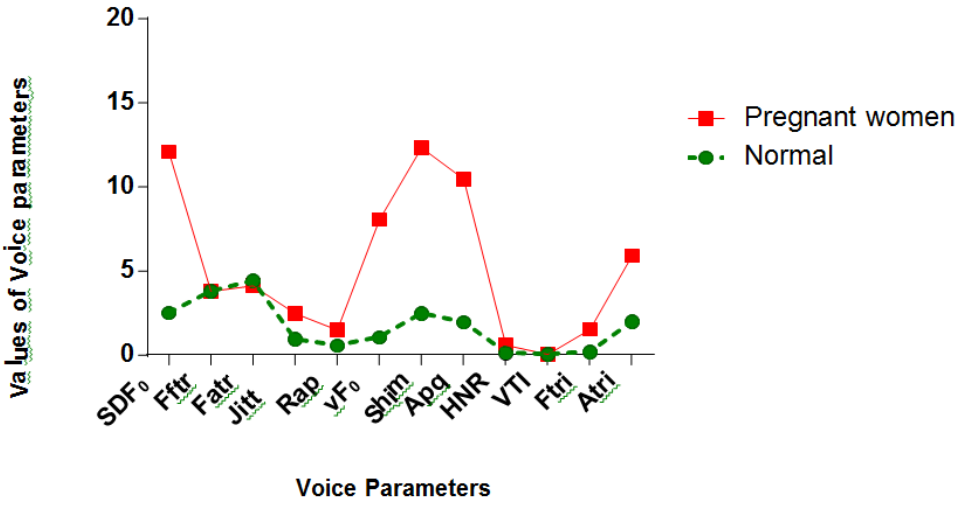
Graph 4.3: Mean value of voice parameters of third trimester pregnant and non-pregnant women for vowel /a/

Above graph indicates third trimester pregnant women had a higher mean value for all MDVP parameters except FATR, HNR, VTI and FTRI for the vowel /a/.



Graph 4.4; Mean value of voice parameters of pregnant and non-pregnant women for vowel /i/.

In above graph, pregnant women had slightly higher mean value for MDVP parameters except FATR, HNR, VTI and FTRI for vowel /i/.



Graph 4.5: Mean value of voice parameters of pregnant and non-pregnant women for vowel /u/.

Graph 4.5 shows third trimester pregnant women had a significant difference in mean values for MDVP parameters such as SDF_0, VF_0, shimmer, APQ and ATRI. But no significant difference noted for parameters such as FFTR, FATR, HNR and VTI for vowel /u/.

HNR shows significant difference between groups for vowels /a/ and /u/, not for vowel /i/ at p> 0.05 level of significance. Marginal difference was observed in MF_0 and VTI for vowel /u/.

Perceptual analysis using GRBAS

The severity ratings of voice dimensions of reading samples of third trimester pregnant women were based on perceptual evaluation carried out by using a 4 point rating scale for the 5 perceptual parameters on GRBAS. The perceptual evaluation

was carried out by 3 experienced Speech-Language Pathologists. The inter-judge reliability was estimated by using Kappa coefficient. The results of the perceptual rating using the GRBAS scale is summarized in the table 4.5 below:

Table 4.5:

Kappa co-efficient value for perceptual evaluation

Kappa Value of Group I			
	J1v/sJ2	**J2 v/s J3**	**J1 v/s J3**
Grade	-0.034	0.009	-0.016
Roughness	0.024	-0.024	-0.095
Breathiness	0.000	0.038	0.000
Asthenia	-0.015	-0.032	0.130
Strain	0.000	-0.046	0.000

Table 4.6:

Mean, SD, and Median of perceptual analysis of GRBAS scale.

	Perceptual measures		
	M	**SD**	**Med**
Grade	0.458	0.298	0.333
Roughness	0.591	0.306	0.666
Breathiness	0.508	0.261	0.500
Asthenia	0.508	0.377	0.333
Strain	0.466	0.327	0.333

The inter judge reliability was poor between judges for all the parameters of GRBAS.

All the grades in GRBAS showed ≤ 0.5 for all individuals in group I which is indicative of slightly deviant voice quality according to perceptual evaluation.

Summary of Results

- Fundamental frequency and **SDF_0** showed significant difference between pregnant and non-pregnant women for vowels /a/, /i/ and /u/.
- Perturbation measures such as**, JITT, RAP, VF_0, SHIM, APQ** showed significant difference between pregnant and non-pregnant women for vowels /a/, /i/ and /u/.
- Tremor measures such as **ATRI, FTRI** showed significant difference between pregnant and non-pregnant women for vowels /a/, /i/ and /u/.
- Noise measure **(NHR)** showed significant difference between pregnant and non-pregnant women for vowels /a/, and /u/.
- Perceptual measures of pregnant women showed greater than 0.5 on GRBAS scale.

CHAPTER 5

DISCUSSION

The particular study focused to estimate the acoustic and perceptual characteristics of voice in third trimester pregnant women and to compare the acoustic voice characteristics in pregnant and non-pregnant women. The current study investigated acoustic characteristics of voice in 30 pregnant women (in third trimester) and 30 non-pregnant women with normal voice quality within the age range of 20-40 years.

Normality test showed non normal distribution. Hence non parametric test was carried out.

Descriptive statistics of acoustic voice parameters

Descriptive statistics showed pregnant women had high values in vowel /u/ in comparison to vowels /a/ and /i/ majorly in parameters such as SDF_0, VF_0, Shimmer, APQ, and ATRI, whereas in non-pregnant women across vowel /a/, /i/ and /u/ no significant variation was found. But while comparing both the groups, the Standard Deviation was very higher in third trimester pregnant women in several parameters. The variability for the pregnant women may be due to vocal fatigue. This is in concordance with the result interpreted by Hamdan *et al.* (2007). Hamdan, Mahfoud, Sibai, and Seoud in 2007 investigated the vocal symptoms and acoustic changes in pregnant women pre and postpartum in comparison to the controls. Result suggested significant decrease in the MPT at term. This decrease is remarkably due to vocal fatigue and alteration of maternal physiology in all levels.

Fundamental frequency and Perturbation measures

Fundamental frequency (F_0) and perturbation measures showed significant difference between pregnant and non-pregnant women for vowels /a/, /i/ and /u/. Comparison of voice parameters across 3^{rd} trimester pregnant and non-pregnant women result suggested significant difference in perturbation measures (STD F_0, JITT, RAP, VF_0, SHM & APQ). F_0, the lowest frequency which is determined primarily by the elasticity, tension, and mass of the vocal folds (Raphael, Borden & Harris, 2007). Increases in the F_0 may be due to elevation of the larynx during pregnancy or increased tension in the laryngeal muscles and vocal fold. Decreased abdominal volume and breathing capacity could be another reason for this finding (Cassiraga *et al.*, 2012).

Perturbation measures such as $STDF_0$, JITT, RAP, VF_0, SHM &APQ showed increment in the pregnant women than non-pregnant women. This may be due to vocal fatigue that they faced during pregnancy. Pregnancy is considered a condition of chronic volume overload. This could have an effect on voice. Since the determinants of pitch are tension, mass, and length. With an increase in mass secondary to the increased water retention witnessed during pregnancy, the vocal fold vibration may be aperiodic in nature than non-pregnant. In contrast to the present study, earlier studies by Satlurk *et al.* (2015) evaluated vocal changes in pregnancy according to trimesters both objectively and subjectively and reported that F_0, jitter, shimmer, and NHR values were not significantly different in many groups in acoustic analysis.

Similar to present study, Cassiraga, Castellano, Abasolo, Abin, and Izbizky (2011) compared voice a attributes between third trimester pregnant and

nonpregnant matched women and reported Most pregnant women showed abnormal parameters in acoustic analysis which could be suggestive of a higher incidence of gastroesophageal reflux, predominance of clavicular breathing, and a reduction of phonation time which can in turn change the voice quality during pregnancy.

Changes in voice characteristics reflect the overall condition of pregnant women. While obtaining medical history several pregnant women have reported of c/o increased weight, vocal fatigue, respiratory distress, GERD and thyroid issues in post conception. These conditions can contribute to the vocal symptoms according to Handan *et al.* (2007).

Tremor and Noise Measures

Tremor measures such as **ATRI, FTRI** showed significant difference in pregnant women than non-pregnant women for vowels /a/, /i/ and /u/. Increase in these parameters indicates the high amount of frequency of tremor in the voice, which again indicates high aperiodicity in the vocal signal caused by the instability and weakness due to the vocal loading and vocal fatigue. Pregnant women generally have physical fatigue due to adaptation metabolic changes happening in the body during pregnancy. This may affect the respiratory system and laryngeal system also. Noise measure (**NHR)** showed significant difference between pregnant and non-pregnant women for vowels /a/, and /u/. This indicate aperiodic component in the voice which shows abnormal noise level in the analyzed sample, which can be due to affected quality of voice. According to Dekron et al. (1995) NHR is the best predictor of roughness. In concurrent to our findings there are similar studies reporting increase in NHR in hyper functional voice disorders (Bhuta *et al.,* 2004; Petrovic-Lazic *et al.,* 2011; Schindler *et al.,* 2012). Increase in NHR is one of the

indicators of hyper functional voice disorder. Furthermore due to the presence of GERD, during the pregnancy also may alter the voice quality, which usually revert after labor (Brodnitz, 1971).

Perceptual evaluation

The result obtained from perceptual analysis of third trimester pregnant women, all the grades in GRBAS showed ≤ 0.5 which is indicative of slightly deviant voice quality. Similar to the result revealed by participants in studies of Hamdan *et al.* (2009) and Adrienne *et al*. (2014), several subjects of present study also reported of vocal fatigue and dehydration during pregnancy. This is can be in agreement with the increase in range of progesterone levels from 100 to 200ng/mL at the term. The effect of the latter is expressed in terms of vocal symptoms, where vocal fatigue became more common in pregnant women compared to controls.

When the respiratory capacity lowers, the subglottic air pressure also reduces; therefore, keeping vocal intensity effortful, which depends on vocal fold vibration range and respiratory airflow (Morrison & Rammage, 1996; Colton, Casper, & Leonard, 2006). By the end of second trimester the stomach of pregnant women is displaced to larger extent. This in turn elicits GER which can often cause hoarseness in voice (Bermudez & Menaldi, 2002; Perez, Cohen, & Arreaza, 2007). As a result of body changes at the thoracic and abdominal level, breathing becomes clavicular (upper portion of the lungs), providing poor respiratory support, which results laborious breathing. This too can contribute the change in quality (Behlau, Madazio, Feij, & Pontes, 2001).

According to Brodnitz, (1971); Koichi, (1997) & Behlau *et al.* (2001), the cause of change in voice quality could be the thickening of vocal fold tissues due to hormonal change during pregnancy.

Present study showed poor inter-judge reliability. Each judge who hears a voice sample evaluate it their own internal standard/reference. The reference is likely to vary across the individuals. Thus, the reliability of such judgments is a central issue in the study of voice quality and voice disorders.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Pregnancy is a period where the metabolic, endocrinologic and physiologic alterations take place which can have effect on every organ system to some extent. Many of these changes lead to symptomatology referable to respiratory and laryngeal system. Thus it is important for the speech language pathologist/voice care professional to be familiar with the changes associated with pregnancy and how these changes are manifested in the vocal system.

All these changes mean that it will likely be more difficult to speak for longer duration due to vocal fatigue and voice breaks which were reported by few subjects while collecting medical history prior to recording of their voice sample. The most important thing to realize is that this is not the time to push your voice to new limits. Accept these limitations, understand that your voice and your body have changed, and provide voice care along with other healthcare. The prevalence of vocal symptoms and the decreased phonation duration should prompt women in their last trimester to decrease strain on their phonatory apparatus, probably by abiding to healthy vocal habits and hygiene. A reduction in the ability to sustain phonation may be compensated for by breathing exercises for better support and control.

The study considered of pregnant women in third trimester and non-pregnant women with normal voice quality within age range of 20-40 years. A total of 60 individuals participated in the study of whom 30 were group I and 30 were group II. Sustained phonation of vowels /a/, /i/, /u/ as well as reading samples were obtained. From the phonation sample, voice parameters were obtained through MDVP. These

samples were also subjected to perceptual analysis by 3 experienced Speech Language Pathologists. The obtained measures of MDVP and the findings of perceptual measures were further subjected to appropriate statistical analysis using SPSS version 20.0.

The result revealed that Fundamental frequency and SDF_0 showed significant difference between pregnant and non-pregnant women for vowels /a/, /i/ and /u/. Similarly Perturbation measures (RAP, VF_0, SHIM, and APQ) tremor measures (ATRI, FTRI**)** showed significant difference between third trimester pregnant and non-pregnant women for vowels /a/, /i/ and /u/. But noise measure (NHR) showed significant difference only for vowels /a/, and /u/ between pregnant and non-pregnant women. Perceptual evaluation of pregnant women enumerated a score greater than 0.5 on GRBAS scale which shows an elevation from the score 0 of non-pregnant women.

These changes in voice characteristics in pregnant women in comparison to non-pregnant women are possibly due to the alteration of maternal physiology in all levels including hormones. In gravid state, changes takes place in larynx causes increased tension in the laryngeal muscles and vocal fold. Pregnancy is considered a condition of chronic volume overload. This could have an effect on voice. Since the determinants of pitch are tension, mass, and length, with an increase in mass. Similarly decreased abdominal volume and breathing capacity could be another reason for this finding. Moreover higher incidence of gastroesophageal reflux, predominance of clavicular breathing, vocal fatigue and a reduction of phonation time which can in turn change the voice quality during pregnancy.

Thus the present study adds on to the literature and understanding of the voice characteristics in third trimester pregnant women in Indian population and further strengthens the notion that hormonal variation takes place in one's body across different life cycle which can have impact on all bodily systems including vocal system.

Implications of the Study

- The outcome of the study will help in characterising voice during pregnancy especially in Indian population.
- The findings of the present study will help the voice clinician for providing awareness of vocal changes to pregnant women especially in third trimester.

Limitations of the Study

- Many pregnant women developed complaint of GERD and thyroid issue post conception, which could not be considered in the present study.
- Within the pregnant women in third trimester, few had difficulty in maintaining the proper posture while performing the task.
- Few subjects could barely cooperate for the analysis due to vocal fatigue and unstable breath support.

Future Directions

- As the present study investigated the voice characteristics in third trimester pregnant women, future studies can assess the changes in voice characteristics across 3 trimesters.
- Similarly a comparison of pre conception, post conception and post-delivery can be made.

- Voice characteristics can be profiled for more number of subjects with other hormonal disorders like thyroid dysfunction, pituitary dysfunction etc., can be considered for further studies.

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APPENDIX

Reading Passages in Malayalam and Kannada (Source: Savithri & Jayaram, 2005)

100 Words Passage- Malayalam

ഒരിടത്ത് ഒരു ബ്രാഹ്മണൻ ഉണ്ടായിരുന്നു. അന്ധവിശ്വാസങ്ങൾക്ക് അടിമയായ അയാൾക്ക് ജീവിതത്തിൽ ഒരുപാടു പ്രശ്നങ്ങൾ നേരിടേണ്ടി വന്നു. തടിയനായിരുന്നതിനാൽ ജനങ്ങൾ അവനെ "പൊണ്ണത്തടിയാ" എന്നു വിളിച്ചു. ആര്, എന്ത് വിശേഷാവസരത്തിനു ക്ഷണിച്ചാലും മുൻപേ ഇവൻ ഹാജരാകുമായിരുന്നു.

ഒരു ദിവസം 'ധനപതി'യെന്ന ബാല്യകാലസുഹൃത്ത് ബ്രാഹ്മണനെ തന്റെ മകളുടെ ജന്മദിനാഘോഷത്തിനായി ക്ഷണിച്ചു. എന്നാൽ, സ്നേഹിതന്റെ വീട് ബ്രാഹ്മണന്റെ വീട്ടിൽ നിന്നും ആറു കിലോമീറ്റർ അകലെ ആയിരുന്നു. നടന്നു പോയാൽ ആരോഗ്യത്തിനു നല്ലത്. കൂടാതെ, കൂടുതൽ വിശന്നാൽ ഭക്ഷണം കൂടുതലും കഴിക്കാം. ബ്രാഹ്മണൻ തീരുമാനിച്ചു.

ജന്മദിനാഘോഷത്തിന്റെ ദിവസം എത്തി. ഒരുക്കങ്ങളെല്ലാം വേഗത്തിൽ നടത്തി വീടിനു പുറത്തേയ്ക്കിറങ്ങിയപ്പോൾ ഒരു കുഷ്ഠരോഗി മുൻപിൽ പ്രത്യക്ഷപ്പെട്ടു. ശകുനം ശരിയല്ലെന്നു പറഞ്ഞ് വീട്ടിനുള്ളിലേയ്ക്കുതന്നെ കയറിപ്പോയി. ഇതുപോലെ മൂന്നു പ്രാവശ്യംകൂടി സംഭവിച്ചു. പിന്നീട് അയാൾ വേഗത്തിൽ നടന്ന് സ്നേഹിതന്റെ വീട്ടിലെത്തി. അപ്പോൾ അവിടെ എല്ലാവരും ഭക്ഷണം കഴിച്ച്, താംബൂലം ചവച്ച് വിശ്രമിക്കുകയായിരുന്നു.

വൈകിവന്ന ബ്രാഹ്മണനെ കണ്ട് ധനപതി "എന്തേ ഇത്ര വൈകിയത്? ഭക്ഷണത്തിനുള്ള സമയം കഴിഞ്ഞുപോയല്ലോ", എന്നു പറഞ്ഞുകൊണ്ട് രണ്ടുവാഴപ്പഴവും പാലും വരുത്തി കൊടുത്തു.