EFFECT OF UPRIGHT AND SUPINE POSTURE ON SOME OF THE ACOUSTIC, AERODYNAMIC AND PERCEPTUAL MEASURES OF SPEECH

Edna Eugine Fernandez

Register No: 11SLP009

A Dissertation Submitted in Part Fulfillment for the Degree

Master of Science (Speech Language Pathology),

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING NAIMISHAM

CAMPUS, MANASAGANGOTHRI

MYSORE-570006

MAY, 2013.

CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Upright and Supine Posture on Some of the Acoustic, Aerodynamic and Perceptual Measures of Speech"*** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech Language Pathology) of the student Registration No.: 11SLP009. This has been carried out the under guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree

Mysore

May, 2013

Dr. S.R. Savithri

Director

All India Institute of Speech and Hearing,

Manasagangothri, Mysore – 570 006

CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Upright and Supine Posture on Some of the Acoustic, Aerodynamic and Perceptual Measures of Speech"*** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore

May, 2013

Mr. R. Rajasudhakar

(Guide)

Lecturer in Speech Sciences

Department of Speech Language Sciences,

All India Institute of Speech and Hearing,

Manasagangothri, Mysore – 570 006.

DECLARATION

This is to certify that this master's dissertation entitled ***"Effect of Upright and Supine Posture on Some of the Acoustic, Aerodynamic and Perceptual Measures of Speech"*** is the result of my own study under the guidance of **Mr. R Rajasudhakar,** Lecturer in Speech Sciences, Department of Speech Language Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore

May, 2013 **Register No. 11SLP009**

Dedicated to....

My ever loving Achan (Late Adv. F Eugine Fernandez),

Amma (Mrs. Ramona Christina Gomez)

Chachaayi (Mr. Antony Eugine F)

&

Ammamma (Mrs.Bridget Gomez).

Acknowledgements

I can do all things through him who strengthens me. _

Philippians 4:13

Thanks to all the readers of this dissertation for sparing your valuable time and taking deep interest in my research outcomes. Here are the people close to my heart, without their support, love and affection, I wouldn't have reached to the other side of this dissertation.

*First of all I would like to thank my **Almighty God** for giving me courage and strength and constantly guiding me throughout my dissertation work.*

*I am grateful to **Prof. S. R. Savithri,** Director, AIISH, Mysore for allowing me to present my research proposal and letting me commence my study.*

*I would like to thank the HOD, Dept. of Speech Language Sciences, **Dr. Y V Geetha** for permitting me to use the instruments and facilities available for my study.*

*My deepest gratitude to my guide, **Mr. R. Rajasudhakar** for all the endless support and instruction throughout this research. I thank him for his patience, for* *his attention to details, and for his patient listening and helping me throughout in completing this precious piece of work of mine.*

I thank ***Vasanthalekshmi Ma'am*** *for helping me with the statistics.*

I thank all the staffs who taught me during these 2 years (Prema Ma'am, Shyamala Ma'am, Geetha Ma'am, Yeshoda Ma'am, Sridevi Ma'am, Santhosh Sir, Goswami Sir, Puspavathi Ma'am, Vasanthalekshmi Ma'am).

I thank ***Dr. N Sridevi*** *who was my external guide and guided me constantly with her valuable suggestions. The most inspiring quote I wrote in my diary was the one which you told in class "This too shall pass… " and it has brought a great impact in my life.*

I thank ***Dr. K Yashoda*** *for giving me permission to conduct the study in the Professional Voice Care Department and also for always giving me mental support and strength to move on with my work and time. "Time has the power to heal everything"- I understood the real meaning after I heard it from you ma'am.*

I thank my ***Achan, Amma, Ammamma*** *and* ***Chachaayi*** *for always being with me and encouraging me in whatever work I do. My love for you in life exists even after my days are gone.*

A special thanks to the special one in my life, ***Joseph Manuel*** *who has always motivated me and made me happy in the deadliest point during the course of my dissertation work.*

*I thank all my dear ones in my family who always wished good for me, especially **Anu Chettan**, **Neetha Chechi** and all my dear cousins.*

*I thank my very dear friends **Shivaji . G. C** and **Matz** for supporting me always and always being with me in my hardships. Love you guys loads and loads.*

*A special thanks to **Reeny Roy** without whom I wouldn't have been able to complete my work on time.*

*I thank my seniors especially, **Arya chechi, Deepthi chechi** and **Amoolya chechi** for extending their helping hands towards me whenever I needed it the most.*

*I thank all my juniors especially, **Liji kutti, Vaani** and **Krishna** for helping me in my work.*

*I thank all my dear friends, **Thulasi, Santhosh, Ceana, Shilpa, Aparajita, Ankita, Sethu chechi, Jyothsna, Nayana, Vijitha** and **Vijaitha** for always being as a part of me.*

*I thank **all my classmates**, (especially Hellows, Mandira, Pooja, Madhu, Amulya, Ramya, Bilva), and my **J C partners** (Avinash, Anku alias Ankita, Mahi alias Mahendra Kumar N) for making my AIISH life so memorable and cherishing…. I will miss you all so much.*

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Communication is the transfer of ideas or information between individuals or a group of individuals. Communication is often referred to as an umbrella term. Communication can take place between individuals in many ways. It need not be always through oral modality. It can be through gestures, sign language, written, verbal (speech) and so on. Communication can broadly be classified into two: Non-verbal communication and Verbal communication. Non-verbal communication does not use language for communication. It can be gestures, eye gaze, pointing etc. whereas verbal communication embeds language for communication. It can be through speech, sign language, written language etc.

Speech is the primary verbal mode of communication in normal population. According to McLaughlin (1998), speech is the physical production of sounds to communicate meaning through the neuromuscular control of the structures of the vocal tract. Speech is the primary means by which language is expressed. It is produced by the co-ordinated movement of the four subsystems of speech mainly, respiratory, phonatory, resonatory and articulatory system. The movements of the speech organs- structures such as lips, tongue, velum and the vocal folds- results in the sound pattern that are perceived by the listener. The end product of speech is an acoustic signal that represents the communicative message of the speaker. The perception of the produced speech can vary depending on the environmental factors like the medium through which sound is propagated, distance between the speaker and the listener, position etc.

The parameters of speech primarily include voice, articulation and fluency. When we refer to speech disorders or abnormality in speech, it focuses mainly on the above mentioned parameters. It can be voice disorder, articulatory disorder, fluency disorder or a combination of any. Any deviances in voice, articulation and fluency to that of age, gender and culture matched individuals is termed as speech disorders.

Assessment of speech will be targeted on profiling all the aspects of speech including voice, articulation, fluency, prosody etc. The procedure for the assessment various with each set up. While certain places use instrumental procedure for evaluation (e.g, acoustic evaluation), others may follow perceptual evaluation procedure. In multispecialty clinics they may even use imaging methods of procedures to find out the exact speech problem. Assessment procedures will not be just looking at the parameters of speech. It starts from the evaluation of the subsystems which supports the speech production.

The production of speech is primarily initiated by the airflow from the lungs (respiratory system), followed by modulation of the upcoming airstream by the laryngeal system (phonatory system) which is again modified by the resonatory and the articulatory system to bring out the utterances. For the production of smooth speech all the subsystems should be working intact and efficiently. The respiratory efficiency is measured through the aerodynamic measures and the phonatory system through the acoustic measures. As a part of speech evaluation speech language pathologist must look into the aerodynamic and acoustic measures for further proceedings.

According to Hixon and Hoit (2005), “Speech breathing is the process by which driving forces are supplied to the speech production apparatus to generate the sounds of oral communication”. Extended steady utterance and running speech activities are the two types of speech breathing out of many (Hixon & Hoit, 2005). Extended steady utterance shows minor or slow changes in the breathing apparatus adjustments. Running speech activities include activities such as reading loudly, extemporaneous speaking and conversational speaking. The demand for breathing apparatus is very much different for running speech activities when compared with the extended steady utterance. During running speech activities the abdominal and the rib cage volumes are decreased at relatively constant rate.

Posture plays a vital role in the production of smooth intelligible speech. Normally speech is produced in an upright sitting or standing position. But there are certain situations like bedside evaluation, dental procedures, MRI investigations etc individual has to be in a supine position. Postural adjustments or correct positioning, particularly in persons who are wheelchair-bound, can be a simple, yet effective measure for improving the respiratory drive for speech (Horton, Murdoch, Theodoras & Thompson, 1997).

Speech breathing changes with body posture primarily because of the influence of gravity. In order to achieve the desired performance the speech breathing requires an alternative mechanical solution, each time the body is re-oriented within the gravity field. In the upright body position, gravity acts in the expiratory direction on the rib cage wall and in the inspiratory direction on the abdominal content and abdominal wall. Thus gravity tends to decrease the size of the ribcage wall and increase the size of the abdominal wall. In supine position the gravitational effect becomes expiratory on both the rib cage wall and abdominal wall. There is less gravitational effect with change in lung volume compared to the upright body position because the height of the abdomen is reduced.

The aerodynamic measures vary in both the positions (upright and supine) due to the differences in the external gravitational load. Not only may the aerodynamic measures, the acoustic measures also vary due the difference mentioned above.

The variables or the factors that affect the speech of an individual in upright position can vary when the subject produces speech in supine position. These factors can be either external or internal. External loads arising as a result of the orientation of body segments relative to gravity can affect the achievement of movement goals. The degree to which subjects adjust control signals to compensate for these loads is a reflection of the extent to which forces affecting motion are represented neutrally. The only external load that affects speech is the gravitational loading (Shiller, Ostry & Gribble, 1999).

The effect of gravitational load on speech can be mainly studied through imaging techniques (Kitamura et al., 2005; Engwall, 2006; Tiede et al., 2000; Stone et al., 2007), point tracking techniques (Shiller et al., 1999), acoustical analysis (Tiede et al., 2000; Stone *et al*., 2007), aerodynamic measures (Priya & Manjula, 2010; Annapoorna, 2009) and perceptual analysis (Tiede et al., 2000).

Need for the study

From the studies quoted above it is seen that not many studies have addressed the issue of influence of body posture on the acoustic or aerodynamic measures of speech. Almost all the studies have focused on the changes that occur in the speech articulators with respect to lips, tongue, jaw and larynx and with the use of sophisticated invasive (EMG) and non-invasive (MRI, Ultrasound, X-ray microbeams etc.) techniques. Non-invasive imaging techniques emit lot of radiation which is harmful for human tissues. People with claustrophobia will be unable to undergo procedures like MRI. These equipments consume more time for evaluation and analysis. The availability of these instruments is less and requires specialized expertise to interpret the data.

Acoustic analysis gives a pavement to resolve all these issues and it is the best way to analyse the variables with respect to speech parameters in different postures. It is easier, feasible, non-invasive, relatively less time consuming and the availability is more for speech language pathologists. Real time measurements can be made with it and it provides feedback system too. It also helps to make pre-post therapy comparisons.

There are very less studies done in Indian context with this aspect. In most of the clinics it is practically impossible to afford the use of any modern or sophisticated imaging devices. These centres rely more on basic acoustic and aerodynamic measuring instruments. Routine speech evaluation including the assessment of aerodynamic measures like vital capacity, maximum phonation duration in supine position would be recommended for patient who is unable to sit in an upright position, especially patients with stroke, paralysis or neuro-degenerative disorders and cerebral palsy. These individuals would show differential breathing pattern and have difficulty in maintaining upright posture. Therefore to look into the variation from normal values, due to gravitational loads, a comparison of acoustical and aerodynamic correlates in the different postures is necessary.

Aerodynamic measures in the upright and supine position helps us to understand how much the respiratory parameters vary with position in relation to gravitational loading. Variations of the tongue height and advancement in the oral tract due to postural differences can be investigated through acoustical measures. Thereby it also helps to understand how much posture plays a role in the intelligibility of speech.

Aim of the study

The present study aims at investigating the effect of posture- upright and supine on acoustic, aerodynamic and perceptual measures of speech in normal adult individuals.

Objectives of the study

- To analyse the acoustic parameters such as formant frequencies (first & second), F1 bandwidth, and acoustic vowel space at two different conditions- upright and supine

- To investigate the effect of posture (upright and supine) on aerodynamic measures like maximum phonation duration (MPD), S/Z ratio, forced vital capacity (FVC), phonation quotient (PQ) and number counts per breathe.

- To analyse perceptually the speech produced at two different postures- upright and supine

- To compare the gender difference, if any, on the above measures.

Brief method of the study

A total of 46 subjects (23 males and 23 females) participated in the study. Speech samples were collected from the participants in both upright and supine postures. The speech samples were subjected to acoustical analysis to compare the difference in acoustic measures (F1, F2, F1 bandwidth and acoustic vowel space), if any, for posture and gender. For aerodynamic measures, MPD, s/z ratio, forced vital capacity, phonation quotient and number counts per breath were measured at the two postures and subjected to comparison. For perceptual measures, one minute speech sample was collected from each subject and given to two judges for perceptual identification of the speech sample.

Implications of the study

1. The results of the study substantiate the role of external gravitational load on different measures of speech in adults and the extent of its contribution on the speech measures.
2. The results of the present study would augment the understanding of acoustic-articulatory changes at different body postures.
3. The results of the study can be clinically applied for individuals affected with stroke, paralysis, cerebral palsy and neurodegenerative disorders or postural disturbances in speech assessment and therapeutic management.

CHAPTER II

REVIEW OF LITERATURE

Speech is always produced under the influence of gravitational force. Normally speech is produced in an upright posture but in certain conditions like dental procedures, MRI recordings, sleeping and so on, the person has to be in supine position. During this posture it is not known whether the articulators compensate for the gravitational loading. The effects of gravitational loading on the speech process and aerodynamics have been studied by several authors. They have used different instrumentation and procedures to reach at their findings and conclusions. Some of the studies reported sustained phonemes have more gravitational effect and some later studies contradict the earlier studies. The studies in the similar line have been explained under four headings; (a) electromyography study, (b) imaging studies, (c) acoustic and perceptual studies and (d) aerodynamic studies.

(a) Electromyography study

Electromyography (EMG) studies were done in the two postures to see the influence of gravitational loading. Myamoto, Ozbek, Lowe and Fleetham, (1997) studied the effect of gravity on tongue movements using EMG and showed greater genioglossus posterior (GGP) activity for some vowels than others, and the change was more noticeable in inspiration than expiration. They found that the anterior part of the tongue was vertically compressed in producing vowel /a/, and they associated this deformation pattern of the tongue with the activation of GGP. The authors found that there was more GGP activity in supine position. The authors concluded that these increased activity of GGP results in various tongue modification like a more anterior or posterior tongue position or maintaining an upright pharyngeal position, as long as the airway was sufficiently open. The above study assessed the tongue movement under gravitational force by using EMG methods, which is an invasive technique. Other active articulators like lips, jaw and velum were not considered in the study.

(b) Imaging studies

Kitamura et al. (2005) used an open type MRI scanner to find the difference in the shape of the vocal tract in two postures that is supine and the upright posture. The MRI technique allows visualization of the speech organs. It allows studying the configuration, geometry and the movement of the organs with very less harm. An open type MRI allows imaging to be done in both upright and supine postures whereas an ordinary MRI scanner does not provide that provision, hence the authors have considered an open MRI scanner for their study which aimed to study on the effect of posture on vowel articulation. The authors took 3 male Japanese subjects for the study within the age range of 35 to 55 years. The subjects were asked to produce five vowels /a/, /i/, /e/, /o/ and /u/ in two positions (upright and supine). In both the conditions the midsagittal magnetic resonance images were obtained. Morphological analysis was carried out to see the postural effects on the production of vowels by superimposing the two images obtained at the two positions for each vowel. The upper and lower lips, mandible, hyoid bone, thyroid cartilage, vocal tract and the cervical spine were outlined and manually traced for the same.

The authors found that there was some effect of posture on the articulation of vowels and that these difference or effects varies from individual to individual. The authors argued that the gravitational force played a substantial role when person was in supine position and this lead to changes in the oral configuration. Tongue would be more posterior and retracted in the supine position when compared with the upright position. For back vowels it was seen that the retraction of the tongue was greater when compared to the front vowels. Laryngeal height variation was also noted by the authors between the two conditions. In supine position, the larynx was higher whereas in upright position it was more lowered which again signified the role of gravitational forces. These changes ultimately resulted in change in shape of the vocal tract as experimentally proved by the authors. The above mentioned study was done on a very few subjects henceforth the results cannot be generalized but it can only be used as a referent to what can happen in the vocal tract when there is a change in the posture of an individual. The study was investigated using an open MRI scanner which is quiet an expensive procedure and unaffordable by every practitioners.

Engwall (2006) used MRI to estimate the effect of sustained articulation and co-articulation in real time in supine and prone position. Only one male Swedish subject participated in the study, the data was recorded from the same person in two occasions with a 2.5 years gap. The author used 3-D reconstruction of tongue surfaces for vowels and fricatives sustained for 5 seconds and midsagittal contours of VCVs in both supine and prone positions were measured. The vowels taken up were /a/, /i/ and /u/. Results indicated that there were overall differences seen in both the condition and the differences were small and varied with phonemes. The effect of gravity was larger for sustained phonemes than running speech (Stone, Kambhamettu, Parthasarathy & Prince, 2007). Even though the difference was small it was prominently shown in the real time during the sustained phonation task and the authors reported that the tongue was more posterior for front vowels in supine position. The authors compared the sustained articulation with the posture and found that there was no difference qualitatively even though the measurement conditions were large. The authors pointed out the reason for larger gravitational effect was due to constricted pharynx with too small air passage at the velum and the lack of velum control during sustained articulation for a long duration without phonation.

The above mentioned study also used imaging technique which cannot be found easily everywhere. It is time consuming and costly procedure where one can know the extend to which the articulators changes its position with posture. It gives us less information about how the speech output is affected because of these changes. So more study should be done to explore the effect of these changes in the speech characteristics, which is clinically relevant.

(c) Acoustic and perceptual studies

Acoustic analysis primarily relates to the study of speech characteristics physically with respect to changes in the fundamental frequency, formant frequencies, transition, and voice onset time and so on. The study here focuses mainly on the vowel characteristic changes which take place across different place of articulation and two conditions- standing and supine postures.

According to Kent and Read (2002), F1 varies mostly with tongue height and F2 with tongue advancement. In general low vowels have high F1 frequency and high vowels have low F1 frequency. Back vowels have a low F2 and a small F2-F1 difference, whereas front vowels have a higher F2 frequency and a larger F2-F1 difference. The vowel space provides a graphical method of depicting a speech sound, such as a vowel, is located in both "acoustic" and "articulatory" space. The vertical axis represents the frequency of the first formant (F1). The horizontal axis shows the frequency gap between the first two formants (F2-F1) or second formant frequency (F2). This 2-dimensional representation corresponds, to a certain degree, to tongue body position, with indications of high vs. low and front vs. back positions – in the oral cavity which is termed as articulatory space or acoustic vowel space.

Shiller, Ostry and Gribble (1999) examined the effect of gravitational loading on speech as this can be the primary loading factor affecting the speech of an individual. They also studied how gravitation plays an important role in the speech production at different postures. Their hypothesis was that no compensation is made by the speech articulators in order to overcome the gravitational loading. They used optotrak to study the jaw orientation and formant frequencies by acoustic analysis for sustained vowel production /e/ and /a/ in upright, supine and prone position in 5 subjects with no history of speech motor disorder or temperomandibular joint dysfunction. The subjects were asked to repeat speech like utterances embedded in a carrier phrase. The authors estimated the formant frequencies of each vowel separately and averaged over consonants to see the effect of head orientation on formant frequencies.

Results indicated that the subjects did not completely compensated for differences in gravitational load and acoustic analysis suggested F1 and F2 frequencies varied significantly depending on head orientation relative to gravity. F1 was higher for /a/ vowel in the upright position when compared to the supine and prone position and it was least in the prone position for 5 out of 6 subjects. In case of F2 of /a/ vowel, it was higher at the prone position for 5 out of 6 subjects. For 1 subject it was high at the supine position and all the subjects showed the least F2 value for /a/ vowel at the upright position. For /e/ vowel, F1 was high in the upright position for 5 out of 6 subjects and F1 was least at prone position for all the subjects. F2 for /e/ vowels was high at prone position in 5 of the 6 subjects and for 1 subject it was high at the supine position and it was least in the upright position in 4 out of 6 subjects. No much difference in value was seen between upright and supine condition and supine and prone condition but slightly significant changes in values were noted between upright and prone position.

The authors concluded that loads caused by the gravitational force affect both oro-facial movements and in turn acoustical values. Also, corrections may be expected only when intelligibility is compromised. Lack of compensation might contribute to the high variability associated with speech. Hence the authors concluded that compensation of the articulators is not achieved completely with changes in head orientation.

The study has focused and well framed the changes in the F1 and F2 characteristics of 2 vowels but has not documented how it changes with the rest of the vowels. Sustained production of /a/ and /e/ vowels are considered in the study but the co-articulatory effects and the different place of articulation effects are not explored much.

Tiede, Masaki and Vatikiotis Bateson (2000) aimed to study the contrast in articulation production, especially tongue and jaw movement using the X-ray microbeam in sitting and supine position. The authors have considered two Japanese male subjects for the study. The subjects were asked to produce sustained vowels, CV sequence in isolation and in carrier context and also sentences in both the condition. For sustained vowel production subjects showed differences. Authors reported that there was upward and anterior tongue movement in supine position and there was also slight posterior jaw position. There was reduced range of jaw movement and reduced opening/closing gestures in supine position reported. Acoustic measures have been abstracted from the samples and looked for variation in formant frequencies and formant bandwidth in the two positions. The authors did not find any major differences in formant bandwidths when they did the acoustical analysis. There was no significant difference in the formant frequencies produced at the two different positions or in context even though there were slight changes in the articulatory positions when compared between the two positions. The authors reported this can be due to the compensatory mechanisms taken up by the articulators. The authors have also conducted a perceptual experiment where a forced- choice paradigm has been used and result indicates that the listeners correctly chose above chance factor.

The above mentioned study has considered a very small sample hence results cannot be generalized to a larger population. Again the use of sophisticated imaging devices are not feasible and seldom present in small clinical set ups. The study was done on Japanese speaking adult individuals hence the changes in their vowel production and other sounds cannot be generalized with the other language speaking population.

Stone *et al*. (2007) used ultrasound imaging to study and estimate the tongue position with respect to gravitational loading. The authors obtained the midsaggital contour for the production of words containing extreme consonant and vowel tongue positions in supine and upright position. The study was basically done to see whether gravity has strong or systematic effect on tongue movements and positions. The authors included 13 subjects in the study (7 males and 6 females) with mean age of 24 years. The participants were asked to repeat short words where consonants /ŋ/, /d/, /ʃ/,

/g/, /l/, and vowels /i/, /a/ and /æ/ were embedded. Recordings were done in both supine and upright positions and looked for the alignment of the palate and the tongue. Subjects were asked to do dry swallow spontaneously in upright and supine positions in order to get the contours of the palate. The tongue contours were extracted from the ultrasound images itself. The range of motion was then calculated in the upright and the supine position. Along with this acoustic analysis was also carried out by the authors using PRAAT software in order to obtain the formants and the formant bandwidth. The authors found that there was a significant difference in the sustained vowel production. The results indicated significant subject difference. Out of the 13 subjects, seven subjects showed more posterior tongue movements in supine position; two subjects showed more anterior tongue position and varied by phonemes for four subjects. No major phoneme effect was reported.

This study was carried out on a small population and hence acoustic results may vary when a large population is considered. The authors reported that the acoustic analysis could not be accomplished completely in the study due to hampering of noise component in the sample from the ultrasound. Hence, the study did not compare the speech production aspects acoustically between supine and upright postures.

(d) Aerodynamic studies

The interaction between the four sub-systems of speech, mainly respiratory, phonatory, resonatory and articulatory systems produces speech. Respiratory device that is the lungs is the primary organ which gives the drive to the other systems. Lungs provide the air which is the primary source of energy.

Speech breathing changes with body positions because of the influence of gravity. Each time the body is reoriented within a gravity field, speech breathing requires an alternate mechanical solution to achieve the desired performance (Hixon & Hoit, 2005). When the body is in the upright position, gravitational force acts on the walls of the rib cage and the abdominal walls. Greater effect of the gravitational force is seen on the abdominal wall than the wall of the ribcage. They also said that the effect of gravity is more prominent at smaller lung volumes. A negative pleural pressure builds up as a result.

When the body is in the supine posture, the effect of gravity becomes expiratory on both the walls of the ribcage as well as the abdomen. There is less gravitational effect with change in lung volume in supine position than in upright position.

According to Hoit (1995) the change in body position from supine to upright dramatically alters the mechanical characteristics of the respiratory system and impedes generalisation across body positions. Phonatory measures are also reported to vary with posture. Analysis of F0 in recorded samples of sustained phonation showed a 1.1 semitone range decrease in the supine position compared to that of the standing position oweing to attenuation at both the upper and lower limits (Fishman & Shipp, 1970; Priya & Manjula, 2010).

Hixon, Goldman and Mead (1973) studied the effect of various body positions on the respiratory behaviour during oral reading and they found that the lung capacities at the resting respiratory level to be about 20% of vital capacity lower in supine position than in the upright position. This was attributed to the gravitational effect by the authors. Comparing the upright to supine position there was less gravitational effect with change in lung volume in the supine position because the height of the abdomen is less (Agostoni & Mead, 1964; Annapurna, 2009).

Vilke, Chan, Neuman and Clausen (2000) studied forced vital capacity (FVC), forced expiratory volume in the first second and the maximum voluntary ventilation (MVV) in the sitting, supine and prone positions in 20 healthy men, aged between 18-50 years. There was significant decline in Spirometry values from sitting to supine and to prone positions. They found significant change in respiratory pattern when changed from sitting to supine or prone position.

Annapurna (2009) studied 120 healthy adults of Dravidian origin who were within the age range of 20-40 years to establish norms for Forced and Slow Vital Capacity in sitting and standing position. The subjects were divided into two groups (20-30 years and 30-40 years). Each group had 30 males and 30 females. The author has taken into consideration of the Body Mass Index and compared the data between gender according to height and weight in both sitting and standing posture. Results indicated that the forced and slow vital capacity was more in standing position than sitting. Males had more vital capacity when compared to females. On comparing between age groups, females had less vital capacity with increasing age whereas males showed higher vital capacity as the age increases in adults. The authors also found individuals with more BMI showed greater vital capacity when compared to lesser BMI.

Priya and Manjula (2010) studied the effect of posture on respiratory and phonatory measures in typically developing children. Two groups of typically developing children were taken in the study within the age range of 3-5 years and 6-8 years. Each group contained 20 children (10 males and 10 females). Four age matched children with cerebral palsy were included in the study (two children- 1 male and 1 female, in each age range) for comparison. The authors measured the vital capacity, maximum phonation duration, breath group and phonation quotient for both typically developing children and children with cerebral palsy under both conditions- upright and supine position. The results indicated significantly reduced values in all the aerodynamic measures in supine position. Male children showed increased vital capacity than female children. Vital capacity was more in standing position when compared to supine position. Similar results were reported for MPD, phonation quotient and breathe count for typically developing children. On comparing the results of the typically developing children with children with cerebral palsy, it has been found that the children with CP have reduced aerodynamic measures. Hence the authors concluded from the study that gravitational load has an effect on respiratory, phonatory and speech measures in typically developing children and children with cerebral palsy at both conditions, supine and upright postures.

There are not many researches or studies done to see the effect of posture on the acoustic and aerodynamic measures of speech. Most of the studies have been done using sophisticated imaging instruments and point tracking devices. They have focused on the changes in articulators when there is change in posture. These kind of imaging instruments cannot be found in all institute set up. They need expertise to interpret the data too. Speech language pathologists primarily use acoustic, aerodynamic and perceptual measures for evaluation. So it is very important to know the changes that happen with respect to posture. Routine speech evaluation including the assessment of aerodynamic measures like vital capacity, maximum phonation duration in supine position would be recommended for patient who is unable to sit in an upright position, especially patients with stroke, paralysis or neuro-degenerative disorders and cerebral palsy. These individuals would show differential breathing pattern and have difficulty in maintaining upright posture. Therefore to look into the variation from normal values, due to gravitational loads, a comparison of acoustical and aerodynamic correlates in the different postures is imperative.

CHAPTER III

METHOD

Participants

A total of 46 subjects (23 males and 23 females) participated in the study. They were within the age range of 40-55 years.

Subject selection criteria

Inclusion criteria

- Subjects with no complaint of speech, language and hearing disorder.
- Subjects with no history of upper respiratory tract infection, asthma, bronchitis, pneumonia or allergic diseases and no history of smoking habits.
- Subjects with no history of laryngeal pathology/ tempero-mandibular joint difficulty at the time of recording.
- Subjects with no history of oro-motor weakness or anatomical deviances
- Subjects whose Body Mass Index (BMI) lies within the normal limit (18.50-24.99), as given by WHO (2004).

Stimulus material

Three long vowels /a:/, /i:/ and /u:/ were selected. Non-words of VCV combinations were included in the study. The initial vowel (V) in the VCV combination was always the long vowel which was followed by consonants of four different place of articulation such as bilabial, dental, palatal and velar. The last vowel was always vowel /a/. Hence, the total numbers of non-words were 12 (3 vowels x 4 place of articulation). Thus, form the stimulus material for acoustic measures. Table 1 shows the details of non-words in the study.

Table 1: *List of non-words*

Sl. no	**Non-words (VCV)**			**Place of articulation**
	Mid-low vowel	*Front-High vowel*	*Back-High Vowel*	
1	/a:ba/	/i:ba/	/u:ba/	Bilabial
2	/a:da/	/i:da/	/u:da/	Dental
3	/a:dha/	/i:dha/	/u:dha/	Palatal
4	/a:ga/	/i:ga/	/u:ga/	Velar

I. Acoustic measures

Procedure

All the measurements were carried out under two conditions: condition1-upright and condition 2-supine. Participants were made to stand in a noise free room. Alignment of head, neck, and back of the body of participants would be maintained in upright position (condition 1). The non-words were embedded in a carrier phrase “Say the word -------- again”. The subjects were asked to repeat the carrier phrase for five times at their comfortable pitch, loudness and rate. The microphone to mouth distance was kept constant at 10 cm for all the participants. The recording of the samples was done using CSL 4500 model (KayPentax, New Jersey, USA). The best of the three utterances repeated by the participants were taken for analysis. In condition 2, the participants were asked to do the same tasks in supine position. For this, participants were made to lie down on a flat surface without any head rest (e.g. Pillow). Physical examination table was employed for participants to lie down.

Analysis

- The steady state portion of the initial long vowel (/a:/, /i:/ and /u:/) in the non-word was selected and measured for first formant frequency (F1) and second formant frequency (F2) in both the conditions. Furthermore, F1 bandwidth was measured from the same. F1 bandwidth provides information about the spread of energy. Also, bandwidth is related to damping. The greater the damping, the greater the bandwidth of the sound. Formant bandwidth generally increases with formant number. Increasing formant bandwidth can reduce the distinctiveness of vowels as the energy of different formants begins to overlap. An optimum bandwidth facilitates the discrimination and identification of vowels and also contributes to the concept of ideal voice quality and intelligible speech (Kent & Read, 2002).
- The F1 and F2 values of three long vowels were plotted on a X-Y plane to depict the acoustic vowel space and this was compared between the two conditions (condition 1 and 2).

II. Aerodynamic measures

Maximum phonation duration (MPD), forced vital capacity (FVC), S/Z ratio, Phonation Quotient and numbers per breath count were measured at two different conditions; standing (condition 1) and supine (condition 2)

Procedure

a) *MPD (Maximum phonation duration)*: The participants were asked to take a deep breath and sustain the vowel /ah/ for as long as possible at a comfortable pitch and loudness level on one exhalation. Minimum of 3 trails were carried out and the longest duration from the 3 trails was taken as the MPD.

b) *Forced vital capacity (FVC):* RMS Helios 701 model Spirometer [Recorders and Medicare Systems (P) limited, Chandigarh, India] Spirometer was used for FVC measurement. The participants were asked to stand comfortably (condition 1) with their back straight, and the mouth piece of the instrument was held in position with tight lip seal. The subjects were asked to blow out as hard and fast as possible and continue blowing until no more air can be exhaled after a deep inhalation. Then, the subject should take another deep breath back in, until the lungs are full. The test was repeated until adequate data was obtained. The same was performed in lie down or supine posture in condition 2.

c) *S/Z ratio:* The participants were asked to take a deep breath and then sustain the sound /s/ for as long as possible, on one exhalation, without straining. The time taken to sustain the sound /s/ was measured. Then, the subjects were asked to sustain the sound /z/ as long as possible. The time taken to sustain the sound /z/ was measured. The S/Z ratio is calculated by dividing the duration of the longest /s/ by the duration of the longest /z/.

d) *Phonation Quotient (PQ)*: The participants were asked to take a deep breath and phonate /ah/ vowel as long as possible at a comfortable pith and loudness through the mouth piece by having adequate lip seal. It is calculated by dividing the vital capacity value by maximum phonation time.

e) *Number counts per breath*: The participants were instructed to count 1, 2, 3, and so on after a deep inhalation on a single breath at his/her comfortable average rate. Total numbers that the participant could count per breath were noted down.

III. Perceptual analysis of speech

One minute speech sample was recorded at two different postural conditions: condition 1-standing and condition 2-supine posture. The participants were asked to narrate themselves for one minute duration. The recorded sample was played to 2 experienced Speech-Language Pathologists who has minimum of 5 years of experience in the field was asked to identify the sample on a binary forced choice condition (i.e. sample recorded in upright or supine position).

Analyses

The measured acoustic, aerodynamic and perceptual parameters were analysed and compared between the two postural conditions (standing vs supine) and between gender (male and female) for any differences.

Statistical analysis

- Descriptive statistical analysis was used to compute the mean and standard deviation of the acoustic and aerodynamic measures between genders.

- Mixed ANOVA was used to examine the main effect and interaction effect among acoustic measures (F1, F2 and F1 bandwidth of /a:/, /i:/ and /u:/), aerodynamic measures (MPD, s/z ratio, phonation quotient, counts per breath and forced vital capacity).

- Three Way Repeated Measures of ANOVA was used to examine whether there is significant difference among the acoustic measures (F1 and F2 of /a:/, /i:/ and /u:/) between genders.

- If there is significant difference in any of the variables in the Three Way Repeated Measures of ANOVA, then Bonferroni pairwise comparisons are made.

- Paired t-test was used to compare the aerodynamic measures (MPD, s/z ratio, phonation quotient, counts per breath and forced vital capacity) between the two positions- upright and supine position.

CHAPTER IV

RESULTS AND DISCUSSION

The present study investigated the effect of upright and supine posture on some of the acoustic measures (F1, F2 and F1 bandwidth of the vowels /a:/, /i:/ and /u:/), aerodynamic measures (maximum phonation duration, s/z ratio, forced vital capacity, phonation quotient and number counts per breath) and perceptual measures of speech. A total of 46 participants (23 males and 23 females) within the age range of 40-55 years participated in the study. Speech recordings were done using CSL 4500 for acoustic measures and RMS Helios Spirometer 701 model for aerodynamic measures. The obtained values were then subjected to statistical analysis using SPSS version 17.

The results of the present study are discussed under the following three sub-headings:-

a) Acoustic measures

b) Aerodynamic measures

c) Perceptual measures

a) ACOUSTIC MEASURES

1. Comparison of F1 of vowels between upright and supine positions in males across four place of articulation

Table 2 shows the mean and standard deviation of F1 values at upright and supine posture in males across three different vowels.

Table 2: *Mean and standard deviation of F1 in males between two postures*

	F1 (Males)					
	Upright			Supine		
	/a/	/i/	/u/	/a/	/i/	/u/
	Mean SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Bilabial	624.65 (97.27)	291.36 (25.52)	347.36 (40.97)	641.34 (106.05)	304.06 (26.11)	361.60 (33.59)
Dental	640.51 (99.38)	291.48 (24.48)	359.47 (42.16)	634.64 (121.73)	300.35 (28.66)	361.21 (35.72)
Palatal	656.56 (97.78)	310.03 (27.74)	365.84 (43.55)	648.56 (115.86)	321.46 (33.62)	367.23 (45.75)
Velar	648.67 (87.41)	295.36 (25.57)	355.07 (43.48)	648.64 (117.78)	305.01 (31.88)	357.66 (40.19)

SD: Standard deviation

While comparing the F1 of vowels across the two postures- upright and supine it was found that vowel /a/ had higher F1 value in upright posture across all the place of articulation except bilabial. The vowels /i/ and /u/ had higher F1 value at supine posture across all the place of articulation.

In upright posture, among the different place of articulation it was found that vowel /a/ had highest F1 values for palatal place of articulation which was followed by velar, dental and bilabial place of articulation. Similar results were obtained for the vowels /i/ and /u/ which showed a highest value for palatal place of articulation, followed by dental, velar and bilabial place of articulation.

In supine position, it was found that vowel /a/ had higher F1 value for velar place of articulation, and then followed by palatal, bilabial and dental place of articulation. Vowel /i/ showed the highest F1 value for palatal place of articulation then, followed by velar, bilabial and dental place of articulation. Vowel /u/ showed greater F1 value for palatal place of articulation then, followed by bilabial, dental and velar place of articulation.

2. Comparison of F1 of vowels for upright and supine positions in female participants at different place of articulation

The mean and standard deviation of F1 values at upright and supine posture in females across three vowels are shown in Table 3.

Table 3: *Mean and standard deviation of F1 in females between two postures*

	F1 (Females)					
	Upright			**Supine**		
	/a/	**/i/**	**/u/**	**/a/**	**/i/**	**/u/**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Bilabial	833.97 (86.96)	335.03 (32.25)	394.41 (36.46)	865.78 (71.93)	348.47 (36.70)	403.37 (44.89)
Dental	858.76 (60.20)	344.46 (42.88)	387.68 (34.83)	873.89 (66.17)	351.64 (32.99)	396.21 (33.96)
Palatal	867.09 (69.70)	346.85 (33.18)	400.19 (35.94)	852.78 (87.95)	363.07 (35.43)	414.66 (76.74)
Velar	855.87 (88.01)	341.05 (31.49)	394.26 (38.72)	872.19 (73.77)	352.46 (33.58)	404.39 (34.83)

SD: standard deviation

While comparing the F1 of vowels between the upright and supine posture, it was found that vowel /a/ had higher F1 value in supine position across all the place of articulation except palatal place of articulation. The vowels /i/ and /u/ had the highest values in supine position when compared to the upright position across all place of articulation.

While comparing the vowel across the place of articulation in upright position, it was found that vowel /a/ and /i/ had the highest F1 value for palatal place of articulation then, followed by dental, velar and bilabial place of articulation. Vowel /u/ also had higher F1 value for palatal place of articulation then, followed by bilabial, velar and dental place of articulation.

In supine position, it was found that vowel /a/ had higher F1 value for dental place of articulation, followed by velar, bilabial and palatal place of articulation. Higher F1 value for vowel /i/ was found for palatal place of articulation, followed by velar, dental and bilabial place of articulation. Vowel /u/ had higher F1 value for palatal place of articulation then, followed by velar, bilabial and dental place of articulation.

Table 4: *Results of Mixed ANOVA for F1*

Source	**df**	**F**	**Sig.**
Place	3	6.508	.000*
Place X Gender	3	.629	.597
Vowel	2	1468.731	.000*
Vowel X Gender	2	69.140	.000*
Position	1	5.332	.026*
Position X Gender	1	.695	.409
Place X Vowel	6	1.044	.397
Place X Vowel X Gender	6	1.009	.420
Place X Position	3	1.524	.211
Place X Position X Gender	3	.101	.959
Vowel X Position	2	.257	.774
Vowel X Position X Gender	2	.259	.772
Place X Vowel X Position	6	1.282	.266
Place X Vowel X Position X Gender	6	.458	.839

(* indicates statistical significant difference at 0.05 level)

Results of mixed ANOVA revealed that there was a significant difference (main effects) obtained for place [F(3,132)= 6.508, p<0.05], vowel [F(2,88)=1468.731, p<0.05] and position [F(1,44)=5.332, p<0.05]. Also, the test revealed there was an interaction effect seen for vowel X gender [F(2,88)= 69.140, p<0.05] and no interaction effect was found for other variables. Table 4 shows the mixed ANOVA test results for F1.

The present study found that the first formant frequency value (F1) was higher at palatal place of articulation and it was least at bilabial place of articulation for the three vowels (/a/. /i/ and /u/) at upright position. Whereas, at supine position it was higher at palatal place of articulation and it was least at dental place of articulation for the vowels at supine position.

The study interestingly found that there is an effect of posture on first formant frequency during the production of vowel /a/. F1 value was high at upright position at all places (except bilabial) and the values got reduced at supine position. The reduced F1 values at supine position can be attributed to gravitational effect. Fant (1960) reported that F1 is inversely proportional to tongue height. For the production of low mid vowel (/a/), the tongue lowers and resulted in higher F1 values. When the person is in supine position, the tongue retracts and gets pulled back due to gravitational effects. As a result, there is reduced distance between tongue and palate. Subsequently, the F1 values decrease in supine position. The results of the present study supports the findings of Shiller et al. (1999) who reported decreased F1 values in supine posture when compared to upright posture.

In females, the postural effect for F1 was not noticed as in males and it needs to be verified further.

3. **Comparison of F2 of vowels between upright and supine positions in males across four places of articulation.**

The mean and standard deviation values of F2 at upright and supine posture in males across three vowels are shown in Table 5.

Table 5: *Mean and standard deviation of F2 in males between two postures*

	F2 (Males)					
	Upright			**Supine**		
	/a/	**/i/**	**/u/**	**/a/**	**/i/**	**/u/**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Bilabial	1142.38	2242.15	775.04	1156.74	2282.92	787.69
	(91.25)	(153.40)	(97.13)	(130.24)	(196.68)	(87.12)
Dental	1196.08	2242.89	828.51	1211.97	2274.81	839.03
	(137.15)	(164.65)	(110.13)	(133.13)	(204.83)	(112.58)
Palatal	1229.52	2204.54	791.96	1240.49	2263.67	832.28
	(130.43)	(157.79)	(68.58)	(115.95)	(212.22)	(99.22)
Velar	1194.43	2249.36	793.78	1245.96	2296.58	844.56
	(114.86)	(158.21)	(60.93)	(104.47)	(195.05)	(83.94)

SD: Standard Deviation

Results of descriptive statistics revealed that the mean and standard deviation of F2 between upright and supine position indicated that vowels /a/, /i/ and /u/ had higher F2 values in supine position when compared to the upright position.

When comparing the vowels among different place of articulation, in upright position, vowel /a/ showed higher F2 value for palatal place of articulation then, followed by dental, velar and bilabial place of articulation. Vowel /i/ had the highest F2 value for velar place of articulation then, followed by dental, bilabial and palatal place of articulation. Vowel /u/ had the highest F2 value for dental, followed by velar, palatal and bilabial place of articulation. In general, higher F2 value was found for dental place of articulation and the least value was found for bilabial place of articulation.

In supine position, vowels /a/, /i/ and /u/ showed higher F2 value for velar place of articulation. Lower F2 value was found for bilabial place of articulation among the three vowels.

4. **Comparison of F2 of vowels between upright and supine positions in females across four places of articulation.**

The mean and standard deviation of F2 at upright and supine posture in females across three vowels are shown in Table 6.

Table 6: *Mean and standard deviation of F2 in females between two postures*

	F2 (Females)					
	Upright			**Supine**		
	/a/	**/i/**	**/u/**	**/a/**	**/i/**	**/u/**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Bilabial	1411.05 (108.28)	2597.49 (281.90)	832.46 (68.31)	1453.09 (142.93)	2650.51 (307.57)	829.83 (62.90)
Dental	1442.55 (102.76)	2661.54 (229.21)	860.51 (165.99)	1499.57 (135.22)	2632.13 (395.31)	855.70 (74.04)
Palatal	1456.21 (117.67)	2521.50 (406.25)	858.29 (89.71)	1437.30 (155.72)	2663.92 (252.64)	893.42 (219.71)
Velar	1464.67 (127.51)	2689.54 (234.55)	849.62 (70.56)	1465.04 (140.83)	2691.46 (242.94)	879.09 (79.12)

SD: Standard Deviation

Results of descriptive statistics shown that the mean and standard deviation of F2 between upright and supine position indicated that the vowel /a/ showed higher F2 values in supine position across all the place of articulation (except palatal). Vowel /i/ showed higher F2 values in supine position across different place of articulation (except dental). Vowel /u/ showed higher F2 values in supine position across all the place of articulation except bilabial and dental place of articulation.

By comparing the vowels across different place of articulation in upright position, it was found that the vowel /a/ had higher F2 value for velar place of articulation then, followed by palatal, dental and bilabial place of articulation. Vowel /i/ showed higher F2 value for velar place of articulation then, followed by dental, bilabial and palatal place of articulation. Vowel /u/ showed higher F2 value for dental place of articulation which is followed by palatal, velar and bilabial place of articulation.

In supine position, vowel /a/ showed higher F2 value for dental place of articulation then, followed by velar, bilabial and palatal place of articulation. Vowel /i/ showed higher F2 value for velar place of articulation then, followed by palatal, bilabial and dental place of articulation. Vowel /u/ had higher F2 value for palatal place of articulation then, followed by velar, dental and bilabial place of articulation.

Table 7: *Results of Mixed ANOVA for F2*

Source	df	F	Sig.
Place	3	4.205	.007*
Place X Gender	3	.362	.780
Vowel	2	2380.496	.000*
Vowel X Gender	2	24.943	.000*
Position	1	12.860	.001*
Position X Gender	1	.174	.679
Place X Vowel	6	1.925	.077
Place X Vowel X Gender	6	.995	.429
Place X Position	3	.964	.412
Place X Position X Gender	3	.886	.450
Vowel X Position	2	.828	.440
Vowel X Position X Gender	2	.056	.945
Place X Vowel X Position	6	1.487	.183
Place X Vowel X Position X Gender	6	.818	.556

(* indicates statistical significant difference at 0.05 level)

Results of mixed ANOVA revealed that there was a significant difference (main effects) obtained for place [$F(3,132)= 4.205$, $p<0.05$], vowel [$F(2,88)=2380.496$, $p<0.05$] and position [$F(1,44)=12.860$, $p<0.05$]. Also, the test revealed there was an interaction effect seen for vowel X gender [$F(2,88)= 24.943$, $p<0.05$] and no interaction effect was found for other variables. Table 7 shows the mixed ANOVA results for F2.

In general, unlike F1, the F2 values were higher in supine posture when compared to upright posture in both males and females. Fant (1960) reported that F2 directly depends on front cavity volume, though erroneously. Lesser the front cavity volume, higher the F2 values.

The tongue retracts and gets pulled back due to gravitational force, when a person is in supine position. The posture of the tongue articulate excessively in the anterior region when the person produce sounds like high vowel /i/ or /u/ steadily. The volume of front oral cavity thus reduces which resulted in increased F2 values in supine posture. The results of the present study are in consonance with the findings of Shiller et al. (1999) who also reported higher F2 in supine posture.

5. **Comparison of F1 bandwidth of vowels between upright and supine positions in males at different place of articulation**

The mean and standard deviation of F1 bandwidth at upright and supine posture in males across four places of articulation are shown in Table 8.

Table 8: *Mean and Standard Deviation of F1 bandwidth between two postures*

	F1 bandwidth (Males)					
	Upright			Supine		
	/a/	/i/	/u/	/a/	/i/	/u/
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Bilabial	239.55 (89.64)	35.63 (16.45)	135.81 (84.03)	262.94 (115.70)	40.02 (13.27)	136.25 (88.59)
Dental	203.12 (104.49)	37.61 (17.87)	142.12 (85.35)	231.33 (105.97)	63.62 (57.78)	152.14 (108.90)
Palatal	213.94 (103.63)	54.46 (41.74)	141.81 (111.03)	237.00 (174.12)	54.19 (27.07)	122.98 (70.30)
Velar	221.94 (112.02)	141.20 (68.63)	134.13 (83.22)	209.89 (149.38)	42.84 (16.32)	117.76 (82.10)

SD: standard deviation

The mean of F1 bandwidth of vowels, in general, was higher in supine posture. The vowel /a/ had higher F1 bandwidth values in supine position across different place of articulation except velar. Vowel /i/ and /u/ had higher F1 bandwidth values in supine position across two place of articulation- bilabial and dental place of articulation.

While comparing the vowels among the place of articulation in upright posture, it was found that in upright position vowel /a/ had higher F1 bandwidth value for bilabial place of articulation then, followed by velar, palatal and dental place of articulation. Vowel /i/ had higher F1 bandwidth for velar place of articulation then, followed by palatal, dental and bilabial place of articulation and vowel /u/ had higher F1 bandwidth for dental then, followed by palatal, bilabial and velar place of articulation. In supine position, vowel /a/ had higher F1 bandwidth for bilabial place of articulation then, followed by palatal, dental and velar place of articulation. Vowel /i/ had higher F1 bandwidth for dental place of articulation then, followed by palatal, velar and bilabial place of articulation. Vowel /u/ had higher F1 bandwidth for dental place of articulation then, followed by bilabial, palatal and velar place of articulation.

6. **Comparison of F1 bandwidth of vowels between upright and supine positions in females.**

The mean and standard deviation values of F1 bandwidth at upright and supine posture in females across four places of articulation are shown in Table 9.

Table 9: *Mean and Standard Deviation of F1 bandwidth between two postures*

	F1 bandwidth (Females)					
	Upright			**Supine**		
	/a/	**/i/**	**/u/**	**/a/**	**/i/**	**/u/**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Bilabial	244.32 (106.72)	59.98 (31.13)	108.67 (81.79)	243.72 (130.26)	63.33 (24.67)	159.38 (122.78)
Dental	370.54 (195.12)	67.85 (33.83)	120.67 (73.43)	227.83 (129.07)	95.49 (68.56)	120.82 (56.20)
Palatal	300.91 (184.71)	73.95 (41.24)	139.92 (92.07)	248.77 (142.86)	73.18 (44.51)	129.66 (61.56)
Velar	290.94 (148.41)	60.41 (27.61)	110.83 (61.73)	317.14 (155.78)	62.02 (33.38)	119.80 (65.21)

SD: Standard Deviation

Results of descriptive statistics revealed that the mean and standard deviation of F1 bandwidth among vowels between upright and supine position indicated that vowel /a/ had higher F1 bandwidth in upright position. Vowel /i/ and /u/ had higher F1 bandwidth values in supine position across the place of articulation (except palatal).

While comparing the vowels among the place of articulation, it was found that in upright position vowel /a/ had higher F1 bandwidth for dental place of articulation then, followed by palatal, velar and bilabial place of articulation. Vowel /i/ and /u/ had higher F1 bandwidth value for palatal then, followed by dental, velar and bilabial place of articulation.

In supine position, vowel /a/ had higher F1 bandwidth value for velar place of articulation then, followed by palatal, bilabial and dental place of articulation. Vowel /i/ had higher F1 bandwidth value for dental place of articulation then, followed by palatal, bilabial and velar place of articulation. Vowel /u/ has higher value for bilabial place of articulation, followed by palatal, dental and velar place of articulation.

Results of mixed ANOVA revealed that there was a significant difference (main effects) obtained for vowel [$F(2,88)=86.115$, $p<0.05$] and there was no significant main effect or interaction effect found for other variables.

In general, F1 bandwidth was different between the postures, i.e. it was higher in supine posture in both males and females when compared to upright position. But the difference was not statistically significant. Increased F1 bandwidth of vowels indicates less sharpness of vowels. That is more spreading of energy of the sound results in less clarity during supine position.

The results of the present study are in consonance with the findings of Tiede et al. (2000) where the authors found that there was no effect of posture on the F1 bandwidth.

7. Comparison of F1 and F2 across different place of articulation.

Pairwise comparison among the different place of articulation was done using Bonferroni test. Bonferroni adjustment for multiple comparison revealed there was a significant difference seen between bilabial versus palatal place of articulation and between palatal versus dental place of articulation at $p<0.05$ level for F1.

Results of pairwise comparison of different place of articulation showed that there was a significant difference found between bilabial versus velar place of articulation at $p<0.05$ level for F2.

The differences in formant frequency value with respect to place can be due to the effects of gravitational loading on the articulators. Production of bilabial sounds requires the movement of jaw. Jaws relatively does not fully compensate for speech production when a person is in supine position (Shiller et al., 1999). And moreover, the tongue will be more retracted back when person is in supine position (Shiller et al., 1999; Kitamura et al., 2005; Engwall, 2006). The tip and the body of the tongue might compensate for the speech production aspect to some extent. But the back of the tongue may have more difficulty in bringing out compensatory strategies as the airway gets narrowed due to the effect of gravity. Hence this may be attributed to the significant difference in formant frequencies with respect to bilabial versus velar place of articulation.

8. Comparison of F1, F2 and F1 bandwidth across the three vowels.

Pairwise comparison among vowels were done using Bonferroni test. Results of Bonferroni adjustment for multiple comparisons for F1, F2 and F1 bandwidth revealed that there was a significant difference noticed among all the vowels, that is, between /a/ and /i/, /a/ and /u/ and /i/ and /u/ were significantly different from each other at 0.05 level.

The vowels /a/, /i/ and /u/ are called basic vowels or point vowels. The other name used for these vowels are the corner vowels. In most of the universal languages, these corner vowels exist.

Distinctively, in the oral cavity, the places of production of these vowels are different. That is /a/ is a low-mid vowel, /i/ is a high front vowel and /u/ is a high-back vowel. The varied and distinct formant frequency of these three basic vowels depends on changes in the tongue placement and height, volume and shape of the oral cavity.

9. Gender difference for F1 across variables (place, vowel and position).

Three way repeated measures of ANOVA was done to see the gender effect on F1 of vowels for male and female participants. Results of the Three way repeated measures of ANOVA revealed significant difference found for F1 between males for place [$F(3,66)=6.571$, $p<0.05$] and vowels [$F(2,44)= 326.801$, $p<0.05$]. Also, there was no significant main effect and interaction effect found for other variables.

In females, three way repeated measures of ANOVA revealed significant difference for position [$F(1,22)= 4.442$, $p<0.05$] and vowel [$F(2,44)= 1771.669$, $p<0.05$] only.

Place

Results of Bonferroni adjustment for multiple comparisons, revealed that there was significant difference noticed when comparing bilabials versus palatal and palatal versus dental place of articulation at $p<0.05$. Other places had not shown any significant gender difference.

Vowel

Pairwise comparison among vowels were done using Bonferroni test. Results of Bonferroni adjustment for multiple comparisons for both F1 and F2 revealed that there was significant difference among all the vowels that is, between /a/ and /i/, /a/ and /u/ and /i/ and /u/ in both the genders at $p<0.05$.

10. Gender difference for F2 across variables (place, vowel and position).

Three way repeated measures of ANOVA was done to see the gender effect on the F2 of vowels. Results of Three way repeated measures of ANOVA revealed significant difference in place [$F(3,66)= 4.885$, $p<0.05$], vowel [$F(2,44)= 1143.137$, $p<0.05$] and position [$F(1,22)= 16.223$, $p<0.05$] noticed. No other significant main effect or interaction effect seen in males.

In females, results of Three way repeated measures of ANOVA revealed significant difference in F2 for vowels [$F(2,44)= 1246.930$, $p<0.05$]. No other significant main effect or interaction effect seen in female population.

Place

Pairwise comparison using Bonferroni adjustment for multiple comparisons, to see the effect of place of articulation on F2 values indicated that there is significant difference when comparing bilabials versus velar and bilabials versus dental place of articulation at $p<0.05$. Other places had not shown any significant gender difference.

Vowel

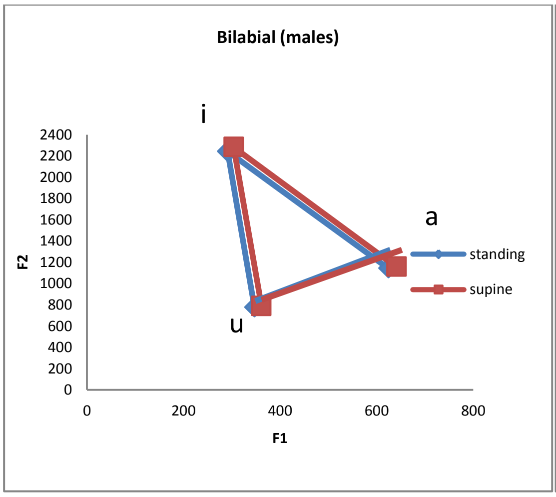
Pairwise comparison among vowels were done using Bonferroni test. Results of Bonferroni adjustment for multiple comparisons indicated that there is significant difference among all the vowels that is between /a/ and /i/, /a/ and /u/ and /i/ and /u/ in both males and females at $p<0.05$.

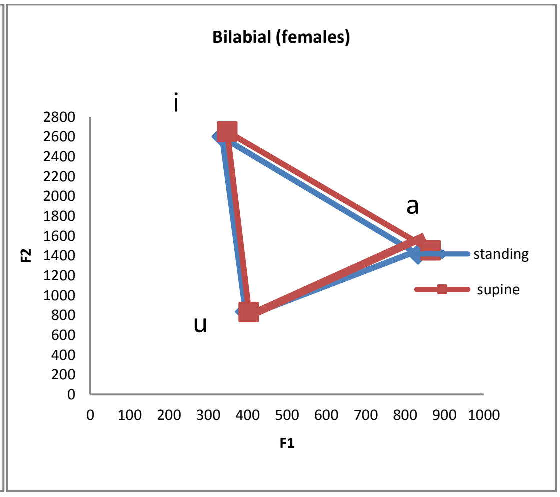
The gender difference in F1 and F2 value with respect to place can be due to the effects of gravitational loading on the articulators. Production of bilabial sounds requires the opening and closing of the jaws, which do not compensate completely when a person is in supine position (Shiller et al., 1999).

Also, in general, the gender difference was noticed among the place of articulation- bilabial versus velar place of articulation. This gender difference could be attributed to the size, strength and thickness of the articulators in term of anatomical aspects between lips versus velum which needs to be investigated further.

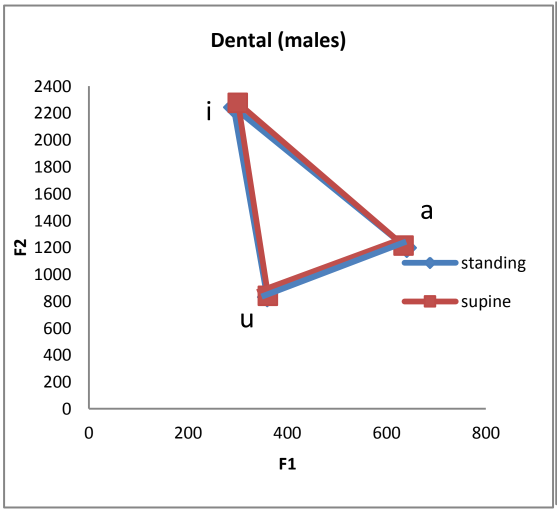
ACOUSTIC VOWEL SPACE

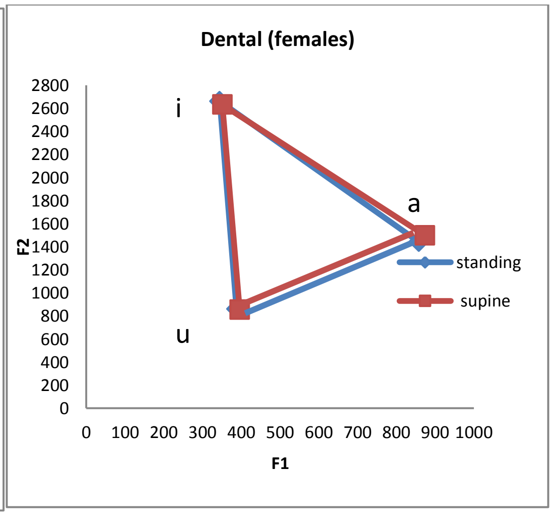
11. Comparison of acoustic vowel space between posture and gender at four different places of articulation.





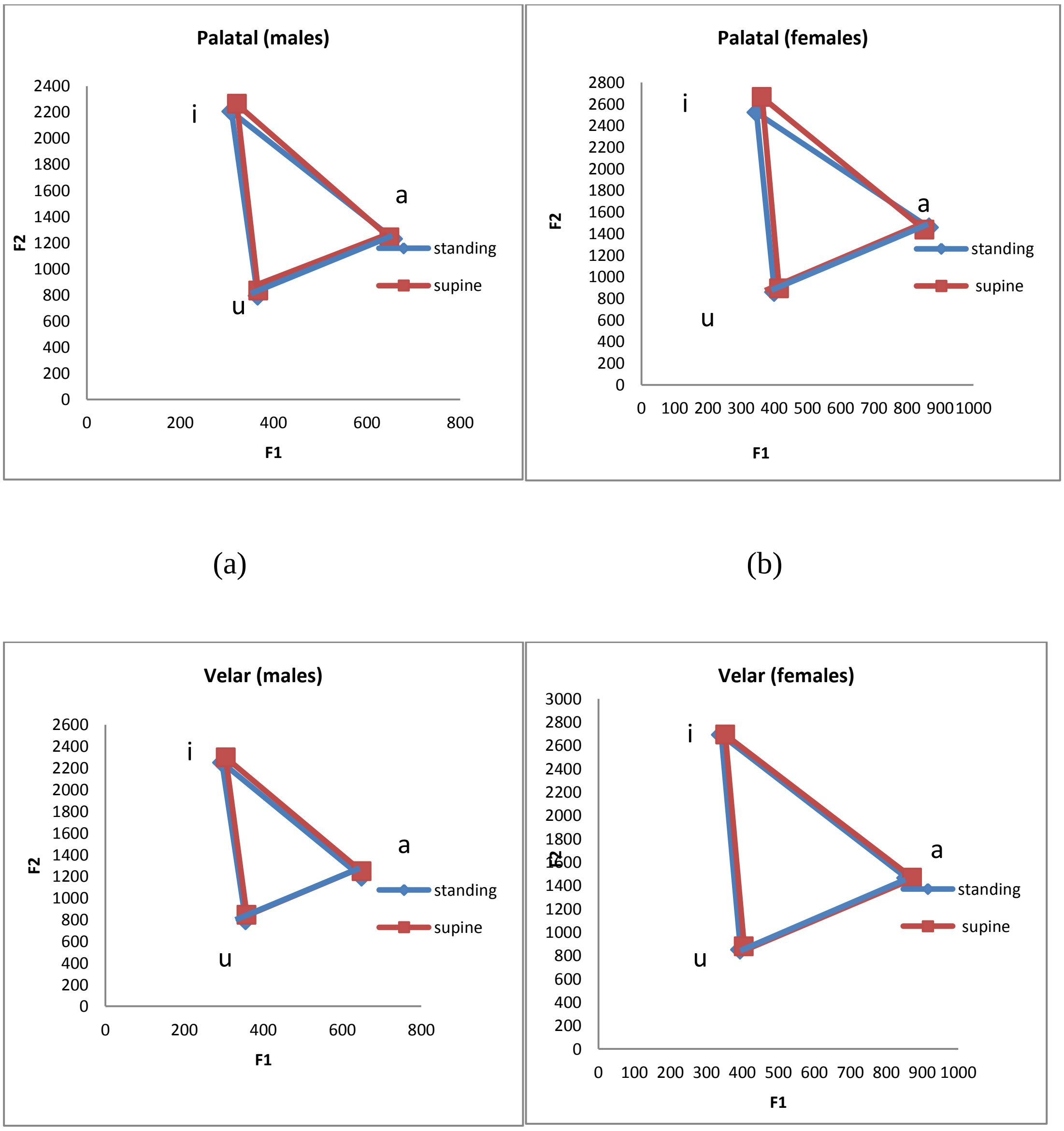
(a) (b)





(c) (d)

Figure 1: Acoustic vowel space between two postures for (a) bilabial-males (b) bilabial-females (c) dental-males (d) dental-females.



(a) (b)

(c) (d)

Figure 2: Acoustic vowel space between two postures for (a) palatal-males (b) palatal-females (c) velar-males (d) velar-females.

Figures 1 and 2 show the acoustic vowel space at two postures- upright and supine for bilabial, dental, palatal and velar place of articulation of the three vowels.

The acoustic vowel space was wider for females when compared to males at two postures- upright and supine postures for all places of articulation. This wider acoustic vowel space in females is because of higher F1 and F2 frequencies in females than males. The acoustic vowel space was relatively wider in supine posture when compared to upright posture. The wider acoustic vowel space in supine posture can be attributed to the increased F2 values of vowel /a/ and /i/ than vowel /u/. Acoustic vowel space depicted in the left bottom quadrant (in upright posture) whereas, the acoustic vowel space moved slightly towards the right upward quadrant in the diagram (figure 1 and 2).

In general, out of the four place of articulation significant shift in the acoustic vowel space was noticed for bilabial and palatal place of articulation and the least changes were seen in the velar place of articulation.

b) AERODYNAMIC MEASURES

12. Comparison of maximum phonation duration between two postures.

Table 10: *Mean and standard deviation of MPD between males and females in two postures*

MPD			
	Gender	**Mean**	**SD**
Upright position	Male	16.78	4.41
	Female	13.30	3.28
Supine position	Male	13.60	4.03
	Female	10.73	2.98

SD: Standard Deviation

The mean and standard deviation of MPD in males and females between upright and supine posture are depicted in table 10. The mean maximum phonation duration was higher in males when compared to females in both the upright and supine postures. When comparing between upright and supine posture, upright position had shown a higher value of MPD than supine posture.

The results of the present study are in agreement with the findings of Priya and Manjula (2010) who reported higher MPD in male children than female children. Furthermore, upright position was reported to have higher MPD value than supine position and the authors pointed out the difference could be because of the effect of gravitational loading on the respiratory system during supine posture.

The reason for higher MPD in males than females can be due to the difference in the general physique of the gender. It has been reported that the size of the ribcage is smaller in females when compared to males and the have a shorter diaphragm

(Bellemare, Jeanneret & Couture, 2003). Males have a higher lung capacity when compared to females which resulted in higher aerodynamic values in comparison to females. A higher MPD value in upright posture can be attributed to the effect of gravitational loading, as reported by Hixon, Goldman and Mead (1973) and Vilke et al. (2000).

Table 11: *Results of Mixed ANOVA for MPD*

Source	**df**	**F**	**Sig.**
Position	1	183.235	.000*
Gender	1	8.689	.005*
Position X gender	1	2.061	.158

(* indicated statistical significant difference)

Results of Mixed ANOVA test revealed that there was significant difference seen in MPD at different positions [$F(1,44)=183.235$, $p<0.05$], and gender effect was also seen [$F(1,44)=8.689$, $p<0.05$]. But, there was no interaction effect seen between posture X gender. Table 11 shows the results of mixed ANOVA for MPD between two postures.

13. Comparison of s/z ratio at upright and supine position in both genders.

Table 12: *Mean and standard deviation of s/z ratio between genders and postures*

	s/z ratio		
	Gender	**Mean**	**SD**
Upright position	Male	1.02	.13
	Female	1.03	.07
Supine position	Male	.93	.11
	Female	.97	.07

SD: Standard Deviation

It was found that the females had relatively higher mean s/z ratio than males. There was a higher value of s/z ratio in upright position when compared to supine position. Table 12 shows the mean and standard deviation of s/z ratio between the two postures.

Table 13: *Results of Mixed ANOVA for s/z ratio*

Source	**df**	**F**	**Sig.**
Position	1	35.937	.000*
Gender	1	0.954	.334
Position X gender	1	2.209	.144

(* indicate statistical significant difference)

Results of Mixed ANOVA for within subject effect indicated that there was a significant difference in s/z ratio at different positions [$F(1,44)=35.937$, $p<0.05$] noticed and there was no significant gender difference or interaction effect seen between posture X gender.

The functional relationship between respiratory and phonatory (voiced/unvoiced) system can be assessed through s/z task. Reduced s/z ratio in supine posture indicates reduced physiological support between respiratory and phonatory system. The results of the present study supports with the findings of Priya and Manjula (2010) where the authors found higher s/z ratio in standing position when compared to supine position.

14. Comparison of forced vital capacity between two postures.

Table 14: *Mean and standard deviation of FVC between genders and postures*

FVC			
	Gender	**Mean**	**SD**
Upright position	Male	1.73	0.38
	Female	1.32	0.33
Supine position	Male	1.38	0.38
	Female	1.13	0.30

SD: Standard Deviation

The males had higher mean FVC than females and when comparisons were made between positions, upright posture showed higher FVC value than supine position. Table 14 shows the mean and standard deviation of FVC between two postural conditions.

Table 15: *Results of Mixed ANOVA for FVC*

Source	**df**	**F**	**Sig.**
Position	1	71.754	.000*
Gender	1	10.828	.002*
Position X gender	1	6.086	.018*

(* indicate statistical significant difference)

Results of Mixed ANOVA test revealed that there was significant difference in FVC at different positions within subjects [$F(1,44)= 71.754$, $p<0.05$], and gender [$F(1,44)= 10.828$, $p<0.05$] and also significant interaction effect between gender and posture [$F=6.086$, $p<0.05$]. Table 15 shows the results of the mixed ANOVA for FVC.

The results of the present study correlate with the findings of Priya and Manjula (2010) who reported higher FVC in males than females. They also reported that the FVC was higher in upright position when compared to supine position. Results of the present study are in agreement with Hixon, Goldman and Mead (1973) study, wherein the authors concluded that 20% of vital capacity lowers in supine position. Vilke et al. (2000) also found similar results.

15. Comparison of phonation quotient between two postures

Table 16: *Mean and standard deviation of phonation quotient (PQ) between genders and posture*

PQ			
	Gender	**Mean**	**SD**
Upright position	Male	108.30	29.04
	Female	102.08	22.51
Supine position	Male	112.39	43.28
	Female	110.50	33.15

Table 16 shows the mean and standard deviation of PQ at two different postures. PQ was higher in male participants when compared to female participants. PQ shows a slightly lower value in upright position when compared with supine position.

Table 17: *Results of Mixed ANOVA for PQ*

Source	**df**	**F**	**Sig.**
Position	1	2.427	0.126
Gender	1	0.211	0.648
Position X gender	1	0.290	0.593

Results of Mixed ANOVA revealed that there was no significant postural difference in phonation quotient within subject [$F(1,44)= 2.427$, $p>0.05$] and gender difference [$F(1,44)= 0.211$, $p>0.05$] found. Table 17 shows the mixed ANOVA results for PQ.

The obtained result is contradicting to the findings of Priya and Manjula (2010) where they found significant postural difference on PQ. This can be due to methodological differences, such as differences in the instrumentation used or differences in selection of the target population which needs to be investigated further.

16. Comparison of number counts per breath between postures.

Table 18: *Mean and standard deviation of number counts per breath between genders and postures*

Number count per breath			
	Gender	**Mean**	**SD**
Upright postion	Male	49.95	13.40
	Female	40.95	11.64
Supine postion	Male	40.21	12.79
	Female	33.65	10.75

SD: Standard Deviation

The mean and standard deviation of number counts per breath at upright and supine posture are tabulated in table 18. The mean number counts per breath were higher in male participants when compared to females. Both males and females counted more numbers in one single breath in upright position when compared to supine position.

The increased number counts per breathe in males can be attributed to the increased vital capacity in males when compared to females. In supine posture the vital capacity is reduced due to the effect of gravity and therefore the number counts per breath is reduced in supine position.

The results of the present study supports the results of Priya and Manjula (2010) where they found counts per breath in upright position was higher than the supine position. They also found males reported higher mean values than females.

Table 19: *Results of Mixed ANOVA for number counts per breath*

Source	**df**	**F**	**Sig.**
Position	1	110.905	.000
Gender	1	4.935	.032
Position X gender	1	2.263	.140

(* indicate statistical sigbificant difference)

Results of Mixed ANOVA indicated that there was a significant postural difference within subjects [F(1,44)= 110.905, p<0.05] seen. Furthermore, significant gender difference between subjects [F(1,44)= 4.935, p<0.05] noticed. There was no significant interaction effect seen between posture and gender [F= 2.263, p<0.05]. Table 19 shows the results of the mixed ANOVA for number counts per breath.

17. Comparison of aerodynamic measures between males and females using paired t test

Table 20: *Results of Paired t-test for comparison between different postures of the various aerodynamic measures*

Paired Samples Test							
		Males			Females		
		t	df	Sig. (2-tailed)	t	df	Sig. (2-tailed)
Pair 1	MPD in upright position - MPD in supine position	11.689	22	.000*	7.878	22	.000*
Pair 2	s/z ratio in upright position - s/z ratio in supine position	5.197	22	.000*	3.247	22	.004*
Pair 3	FVC in upright position – FVC in supine position	5.954	22	.000*	7.592	22	.000*
Pair 4	PQ upright position – PQ supine position	-.623	22	.540	-1.825	22	.082
Pair 5	counts per breath upright position - counts per breath supine position	6.899	22	.000*	9.230	22	.000*

(* indicate statistical significant difference)

Paired sample t-test was done to compare gender difference in various aerodynamic values at two positions indicated that there was significant difference in MPD (t=11.689, p<0.05 for males and t=7.878, p<0.05 for females) , s/z ratio (t=5.197, $p<0.05$ for males and t=3.247, $p<0.05$ for females), FVC (t=5.954, $p<0.05$ for males and t=7.592, $p<0.05$ for females) and number counts per breath (t=6.899, $p<0.05$ for males and t=9.230, $p<0.05$ for females). Paired sample t-test (t=-.623, $p>0.05$ for males and t=-1.825, $p>0.05$ for females) indicated no significant difference in the phonation quotient between postures. That is, except PQ, all other measured aerodynamic measures showed significant gender difference between two postures. Table 20 shows the paired t-test results for males and females between two postures.

The results of the present study support the finding of Priya and Manjula (2010), where the authors have found postural differences in the aerodynamic measures. They found higher aerodynamic values in upright posture when compared to supine posture. The present study also found similar results.

c) PERCEPTUAL MEASURES

18. Comparing the percentage of correct perceptual identification.

The present study found that the percentage correct identification was higher (67%) for male speech sample by both judges. The average percentage correct identification for female speech sample by both the judges was 55%. In general, it was found that perceptually speech could be identified between the two postures above chance factor. Table 21 shows the percentage correct identification by the two judges.

Table 21: *Percent correct identification by two judges*

	Males		**Females**	
	Judge 1	**Judge 2**	**Judge 1**	**Judge 2**
Percentage correct	69.56	65.21	54.34	56.52

Table 22: *Kappa Coefficient value between two judges*

		Judge 1		
		Supine	**Upright**	**Total**
Judge 2	**Supine**	29	13	42
	Upright	15	35	50
Total		44	48	92

The measure of agreement between the two judges was calculated using Kappa Coefficient. The obtained Kappa coefficient was 0.4 at $p < 0.001$ which indicated a significant agreement between the two judges on perceptual measures. Table 22 shows the Kappa coefficient for agreement between the two judges.

The present study supports the findings of Tiede et al. (2000) where the recorded sample were given to judges to rate them on a forced choice paradigm. The authors reported that the perceptual agreement between judges were above chance factor.

The perceptual judgement was made according to the rate, loudness and quality of speech by the judges. In the present study, the judges reported that speech in supine posture was less loud and there was articulatory imprecision which resulted in an overall mild breathiness and mild hypernasality in the voice. The above information was collected as open ended question. Breathy component in the voice can be due to raised larynx when the person is in the supine position (Shiller et al., 1999). Mild hypernasality can be attributed to the incomplete closure of the velopharyngeal port due to the effect of gravitational loading. The reason for these imprecisions and breathy component in the voice can be attributed to the reduced compensatory mechanism of the speech articulators and retraction of the articulators which may reduce the overall size of the oral cavity resulting in resonance changes.

The subjective report of judges on perceptual analysis correlates with the objective findings of the present study. That is, articulatory imprecision, mild breathiness and hypernasality during supine posture were associated with the increased F1 bandwidth values of vowels. Increased F1 bandwidth indicates reduced sharpness of vowels, thereby deterioration of speech intelligibility during supine posture.

CHAPTER V

SUMMARY AND CONCLUSION

"Speech breathing is the process by which driving forces are supplied to the speech production apparatus to generate the sounds of oral communication"- Hixon and Hoit (2005). Speech is produced by the co-ordinated process of the four subsystems- respiratory, phonatory, articulatory and resonatory system. The production of speech is primarily initiated by the airflow from the lungs (respiratory system), followed by modulation of the upcoming airstream by the laryngeal system (phonatory system) which is again modified by the resonatory and the articulatory system to bring out the utterances.

Normally speech is produced in an upright sitting or standing position. Speech breathing changes with body posture primarily because of the influence of gravity. In order to achieve the desired performance the speech breathing requires an alternative mechanical solution, each time the body is re-oriented within the gravity field. In the upright body position, gravity acts in the expiratory direction on the rib cage wall and in the inspiratory direction on the abdominal content and abdominal wall. Thus, gravity tends to decrease the size of the ribcage wall and increase the size of the abdominal wall. In supine position the gravitational effect becomes expiratory on both the rib cage wall and abdominal wall. There is less gravitational effect with change in lung volume compared to the upright body position because the height of the abdomen is reduced.

The variables or the factors that affect the speech of an individual in upright position can vary when the subject produces speech in supine position. These factors can be either external or internal. The only external load that affects speech is the gravitational loading (Shiller, Ostry & Gribble, 1999).

There are not many researches or studies done to see the effect of posture on the acoustic and aerodynamic measures of speech. Most of the studies have been done using sophisticated imaging instruments and point tracking devices. They have focused on the changes in articulators when there is change in posture. These kind of imaging instruments cannot be found in all institute set up. They need expertise to interpret the data too. Speech language pathologists primarily use acoustic, aerodynamic and perceptual measures for evaluation. So it is very important to know the changes that happen with respect to posture. Routine speech evaluation including the assessment of aerodynamic measures like vital capacity, maximum phonation duration in supine position would be recommended for patient who is unable to sit in an upright position, especially patients with stroke, paralysis or neuro-degenerative disorders and cerebral palsy. These individuals would show differential breathing pattern and have difficulty in maintaining upright posture. Therefore to look into the variation from normal values, due to gravitational loads, a comparison of acoustical and aerodynamic correlates in the different postures is imperative.

The present study made an attempt to investigate the effect of upright and supine posture on some of the acoustic (F1, F2 and F1 bandwidth of the vowels /a:/, /i:/ and /u:/ and acoustic vowel space), aerodynamic (Maximum phonation duration, s/z ratio, forced vital capacity, phonation quotient and number counts per breath) and perceptual (percent correct identification) measures.

A total of 46 typical adult individuals (23 males and 23 females) participated in the study. To obtain the acoustic measures, the subjects were asked to repeat the carrier phrase containing the non-word in the VCV combination in both upright and supine condition. The initial vowel was three basic vowels (/a:/, /i:/ and /u:/) and the second consonant contain four different place of articulation (bilabial, dental, palatal and velar). Total of 12 non-words (3 vowels X 4 place) which were embedded in a carrier phrase and the subject was made to repeat it. The samples were recorded using CSL 4500 model and subjected to further analysis to extract the formant frequencies (F1 and F2) and first formant bandwidth of the three vowels (from the initial vowel of **V**CV) at four places of articulation. The aerodynamic parameters like maximum phonation duration (MPD), forced vital capacity (FVC), S/Z ratio, phonation quotient and number counts per breath were measured at two different postures; upright and supine. The data was subjected to statistical analysis to find significant main effect and interaction effect (mixed ANOVA), to find gender difference (three way repeated measures of ANOVA) and paired t-test to find the postural difference in the measured aerodynamic measures.

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

First, the posture had significant effect on first formant frequency during the production of vowel /a/. That is, F1 was higher at upright posture for all places of articulation and the F1 value got reduced at supine posture. The reduced F1 value at supine posture can be attributed to gravitational effect. The present finding supports the findings of Shiller et al. (1999).

Second, the posture had significant effect on second formant frequency during the production of vowels in both the genders. Increased F2 in supine posture indicate that the tongue movement was excess in the anterior region of oral cavity. The present findings are in consonance with the findings of Shiller et al. (1999) who reported higher F2 in supine posture. Also, Kitamura et al. (2005) observed that the tongue retraction was less for front vowels in supine posture.

Third, F1 bandwidth was not influenced by postural differences. Tiede et al. (2002) also found the similar results. That is, there was no effect of posture on F1 bandwidth. No change in F1 bandwidth between two postures indicates the sharpness of vowels and the spreading of energy is similar in the vowels produced at both postures. So the intelligibility of speech does not altered in supine position due to some internal compensation that happen which needs to be investigated.

Fourth, the acoustic vowel space was wider and moves towards right upper of the quadrant in supine posture. Also, females had wider acoustic vowel space compared to males because of higher F1 and F2 values.

Fifth, there was a significant gender difference found for F1 and F2 and not for F1 bandwidth. Females had higher F1 and F2 values compared to males. The difference in formant frequencies between males and females can be attributed to their fundamental frequency differences and the anatomical difference of vocal tract (size, shape, length and volume).

Sixth, aerodynamic measures like mean MPD, s/z ratio, FVC, and number counts per breath were higher in upright posture when compared to supine posture. The decreased aerodynamic measures can be attributed to postural insufficiency and inadequacy due to the increased effort put on ribcage and diaphragm. This finding supports the findings of Hoit (1995) who reported that the behaviour of breathing apparatus differs significantly depending on body position. The main causative factor for this is gravitational effects on the inherent recoil forces of the respiratory apparatus. All the aerodynamic parameters reduced in supine position emphasising the gravitational load on respiratory phonatory and speech related measures.

Seven, significant gender difference found for aerodynamic measures, that is, males had higher aerodynamic parameters than females. The higher aerodynamic parameters in males are because of anatomical (size) and physiological differences in the respiratory apparatus (Kent, 1997).

Eight, the correct perceptual identification of speech uttered in different postures was 67% (for males) and 55% (for females). The forced choice listening paradigm was used to evaluate how well subjects were able to distinguish between speech samples produced in upright and supine postures. The present study found, it was above chance factor and this supports the results of Tiede et al. (2000).

Hence, the conclusion from the present study is that there is an effect of posture on acoustic, aerodynamic and perceptual measures of speech. Henceforth in clinical practice one has to keep in mind the importance of posture while doing assessment or management. While doing bedside evaluation or any form of assessment procedures where the client has to be in the supine position, it should be always kept in mind that a change in posture can bring about changes in the expected outcomes.

Implications of the study

1. The results of the study substantiate the role of external gravitational load on different measures of speech in adults and the extent of its contribution on the speech measures.
2. The results of the present study would augment the understanding of acoustic-articulatory changes at different body postures.

3. The results of the study can be clinically applied for individuals affected with stroke, paralysis, cerebral palsy and neurodegenerative disorders or postural disturbances in speech assessment and therapeutic management.

Limitations of the study

1. A smaller age group and limited age range was included for the study.
2. In the present study, limited parameters were considered for acoustic and aerodynamic assessment.
3. In the present study the assessment of various parameters is limited to only two posture viz upright and supine.
4. The present study was limited only to VCV context.

Future research direction

1. The study can be replicated using wider age range and varied age group, especially the geriatric population, as the prevalence of neurodegenerative disorders is relatively high among these population.
2. The study can be replicated incorporating various temporal aspects and various aerodynamic parameters.
3. It can be further studied using various other postures like prone, semi-upright posture etc.
4. The study can be replicated using stimuli in various combinations like CVC, CCV, VCC etc.

References

Agostoni, E, & Mead, J. (1964). Statics of the respiratory system. (Editors) In: Fenn WO, Rahn H. *Handbook of Physiology,* Respiration Vol. I. Washington, DC: American Physiological Society; p. 387-409, 82 (1), 89-95.

Annapurna, S. (2009). Norms for Forced and Slow Vital Capacity in Adult Dravidian Population. Unpublished Dissertation submitted to the University of Mysore, Mysore.

Bellemare, F., Jeanneret, A., & Couture, J. (2003). Sex Differences in Thoracic Dimensions and Configuration. *American Journal of Respiratory and Critical Care Medicine, 168,* 305-312.

Engwall, O. (2006). Assessing MRI measurements: Effects of sustenation, gravitation and coarticulation, (Editors) J. Harrington and M. Tabain. *Speech production: Models, Phonetic Processes and Techniques,* (Psychology Press, New York), pp. 301–314.

Fant, G. (1960). Acoustic Theory of Speech Production. Morton, The Hague.

Fishman, B. V. & Shipp, T. (1970). Subject positioning and phonation range measures. *The Journal of the Acoustical Society of America, 48(2A),* 431-432.

Hixon, T.J., Golman, M., & Mead, J. (1973). Kinematics of the chest wall during speech production: Volume displacement of the ribcage, abdomen, and lung. *Journal of Speech and Hearing Research, 16,* 78-115.

Hixon, T.J & Hoit, J. (2005). *Evaluation and Management of Speech Breathing Disorders: Principles and Methods.* Redington Brown LLC, Tucson, Arizona.

Hoit, J. (1995). Influence of body position on breathing and its implication for the evaluation and treatment of speech and voice disorders. *Journal of Voice*, 9, 341-347.

Horton, S. K., Murdoch, B. E., Theodoros, D. G., & Thompson, E. C. (1997). Motor speech impairment in a case of childhood basilar artery stroke: Treatment directions derived from physiological and Perceptual assessment. *Pediatric Rehabilitation*, 1(3), 163-177.

Kent, R. D., & Read, C. (2002). The Acoustic Analysis of Speech. Madison: Singular Publishing Group, Inc.

Kent, R. (1997). The Speech Sciences. San Diego: Singular Publishing Group, Inc.

Kitamura, T., Takemoto, H., Honda, K. Shimada, Y., Fujimoto, I., Syakudo, Y., Masaki, S., Kuroda, K., Oku-uchi, N., & Senda, M. (2005). Difference in vocal tract shape between upright and supine postures: Observations by an open-type MRI scanner, *Acoustic Science & Technology*, 26, 465–468.

McLaughlin, S. (1998). *Introduction to Language Development.* Oklahoma, 12, Thomson Learners Publishers.

Myamoto, K., Ozbek, M. M., Lowe, A. A., & Fleetham, J. A. (1997). Effect of body position on tongue posture in awake patients with obstructive sleep apnea, *Thorax*, 52, 255-259

Priya, M. B., & Manjula, R. (2010). Effect of Posture on Respiratory and Phonatory Measures in Typically Developing Children: Implications in Cerebral Palsy. *Journal of Indian Speech and Hearing Association*, 24(2), 109-120.

Shiller, D. M., Ostry, D. J., & Gribble, P. L. (1999). Effects of gravitational load on jaw movements in speech, *Journal of Neuroscience*, 19, 9073–9080.

Stone, M., Sutton, M. Parthasarathy, V., Prince, J., Li, M., & Kambhamettu, C. (2007). Comparison of speech production in upright and supine position, The *Journal of the Acoustic Society of America*, 122(1), 532-541.

Tiede, M. K., Masaki, S., & Vatikiotis-Bateson, E. (2000). Contrasts in speech articulation observed in sitting and supine conditions, *Proceedings of the 5th Seminar on Speech Production.* Bavaria, pp. 25–28.

Vilke G.M, Chan T.C, Neuman T, & Clausen J.L. (2000). Spirometry in normal subjects in sittng, prone and supine positions. *Respiratory Care, 45(4),* 407-410.

World Health Organisation (WHO, 2004), In S, Annapurna (2009). Norms for Forced and Slow Vital Capacity in Adult Dravidian Population. Unpublished Dissertation submitted to the University of Mysore, Mysore.