DEVELOPMENT OF NORMATIVE DATABASE IN ADULTS FOR THE MOTOR SPEECH PROFILE

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INTRODUCTION

Speech is one of the most complex aspects of human beings. Despite being complex, it is acquired seemingly effortlessly. On an average, we speak about 300 syllables per minute or about 14 distinguishable speech sounds per second through the interplay between several muscles innervated by multiple cranial and spinal nerves (Brodal, 1998). Since speech production involves large scale complexities, it is necessary that muscles, nerves, and higher cortical structures maintain structural and physiological integrity. Even minute deviations can alter speech sound production rendering speech abnormal. It has been contended that speech variations form the early cues of any underlying neurologic disorder. In such contexts, recognizing the meaning of specific speech signs and symptoms can provide important cues about the underlying pathophysiology and localization of neurologic disease.

Components of speech production

The basic components of speech production include respiration, phonation, resonance, articulation, and prosody. The exhalatory air stream serves as transmission medium for speech. The diaphragm, thoracic, and abdominal muscles are major elements that participate in respiratory control for speech. At phonatory level, vocal phonation is induced by interaction of several intrinsic and extrinsic laryngeal muscles. The key elements in voice production are the vocal cords which periodically move towards and away from each other during the process. The higher regions of the vocal tract above vocal cords form acoustic resonance chambers. Depending on the position of velum, speech output sounds either oral or nasal. Hypernasal resonance is commonly seen in different types of dysarthria suggesting inefficient control over the muscles that control velopharyngeal port. The speech sound production is brought about by coordinated action of muscles of articulators including tongue, lips, velum, among others. The speech sounds are distinguished by features of place of articulation and manner in which airstream is directed through the vocal tract. The resultant speech output is superimposed by prosodic components of intonation, stress, and rhythm which are brought about by modification in fundamental frequency (F0), temporal, and intensity dimensions. The prosodic variations are the result of interplay between the different subsystems of speech production.

Neurological basis of motor speech system

The speech motor system contains the complex network of structures and pathways that organize, control, and execute movement. It resides at all levels of nervous system and mediates many activities of striated and visceral muscles. Speech motor systems organization and basic operating principles is necessary to understand normal speech production and motor speech disorders. The motor system can be organized according to its functions, as well as its anatomy. On functional basis four major divisions of the motor system can be delineated - final common pathway, direct activation pathway, indirect activation pathway, and control circuits. A fifth division, the conceptual-programming level, is also essential to speech; it includes planning and programming processes (Duffy, 2005).

Table 1: Functional and anatomical divisions of the motor system that are relevant to speech production

Major Division	Basic Function	Major Structures	Related Designations
Final Common Pathway	Stimulates muscle contraction & movement. Other motor divisions must act through it to influence movement	Cranial nerves Spinal nerves	Lower motor neuron system
Direct Activation Pathway	Influences consciously controlled, skilled voluntary movements	Corticobulbar tracts Corticospinal tracts	Upper motor neuron system, direct motor system, pyramidal system or tracts
Indirect Activation Pathway	Mediates subconscious, automatic muscle activities including posture, muscle tone, & movement that support and accompany voluntary movement	Corticorubral tracts Corticoreticular tracts Rubrospinal, reticulospinal, vestibulospinal, & related tracts to relevant cranial nerves	Upper motor neuron system, indirect motor system, extrapyramidal system or tracts
Control Circuits	Integration or coordination of sensory information & activities of direct & indirect activation pathways to control movement.		
Basal ganglia	Plan & program postural & supportive components of motor activity	Basal ganglia, substantia nigra, subthalamus, cerebral cortex.	Extrapyramidal system
Cerebellar	Integrates & coordinates execution of smooth, directed movements	Cerebellum, cerebellar peduncles, reticular formation, red nucleus, pontine nuclei, inferior olive, thalamus, cerebral cortex	Cerebellum

Motor speech disorders

The motor speech disorders are caused by neurological damage leading to deficits in motor programming or execution of speech. They can be developmental or acquired in nature. They are associated with disorders that affect any portion of either central or peripheral nervous system (Duffy, 2005). The characteristics and degree of speech difficulties that result may depend upon several factors, including the type and severity of the underlying etiology, neuroanatomic sites of involvement, coexistence of other disabilities. The speech disorders usually associated with neurologic disease are dysarthria and apraxia of speech.

Dysarthria

It is a group of speech disorders characterized by disturbances in muscular control of the speech mechanism manifested by weakness, slowness, or incoordination. It results due to damage to the central or peripheral nervous system or both. Dysarthria can cause disturbances in on one or more components of the speech production system - respiration, phonation, resonance, articulation, and prosody (Darley, Aronson, & Brown, 1969). The respiratory disorders symptomatology includes low, restricted, weak, or uncoordinated muscles activity during breathing for speech. The phonatory disorders are manifested by harsh, hoarse, or breathy voice quality while hypernasality characterizes resonance disorder. Persons with dysarthria also experience misarticulations of speech sounds. The site of lesion in dysarthria typically involves impairment of the upper motor neuron system, the lower motor neuron system, the cerebellum, the extrapyramidal system, or combinations of these areas. The lesion site leads to different types of dysarthria. Additionally, dysarthria may occur in any of the neurological disorders such as stroke, brain injury, Parkinson’s disease, amyotrophic lateral sclerosis (ALS), multiple sclerosis, Huntington’s disease, cerebral palsy, and tumors (Duffy, 2005).

Classification of dysarthria

The dysarthria classification is usually based on site of lesion and associated perceptual speech characteristics. Darley, Aronson, & Brown (1969) correlated resultant speech symptomatology with lesion site in 2000 clients with dysarthria. They found variations in speech characteristics according to pathology in different regions of the nervous system. They suggested different types of dysarthria can be differentiated according to specific perceptual dimensions of pitch, loudness, voice quality, respiration, prosody, and articulation. Based on etiology, Darley et al., (1969) identified six different types of dysarthria. The spastic dysarthria results from lesions to the pyramidal tract. The speech of spastic dysarthria is characterized by harsh, strained, or strangled vocal quality, imprecise articulation, and irregular prosody. The hypokinetic (substantia nigra) and hyperkinetic (basal ganglia) dysarthria occur when the extrapyramidal tract is damaged. The hyperkinetic dysarthria is usually seen in Huntington's chorea. Speech characteristics of this group of dysarthria involve tremulous voice; variation in rate, pitch, and volume; and imprecise articulation. In hypokinetic dysarthria associated with Parkinson's disease the speech features include monotonous loudness and pitch, reduced stress, imprecise articulation, inappropriate pause, short spurts of speech, variable rate of speech, and breathy, harsh voice quality (Ramig, 1986). The flaccid dysarthria is caused by damage to lower motor neurons (cranial nerves). The characteristic feature is the weakness of muscles involved in speech production. Some of the features of this type of dysarthria are imprecise consonants, low volume, hypernasal resonance, among others. The lesion site for ataxic dysarthria is in the cerebellum. Some of the primary characteristics of ataxic dysarthria are reduced speech rate, inappropriate emphasis, inconsistent vocal volume, and inadequate coordination of respiration and phonation.

Apraxia of speech

Following linguistic planning, the positioning and movement of articulators must be programmed for the information to be relayed to corresponding muscles of the speech production system. In apraxia of speech, the individuals face difficulty in speech motor programming (Darley et al., 1969). Apraxia of speech can occur in the absence of any significant neuromuscular weakness, disturbances of conscious thought or language (Darley et al., 1969). The lesion site in apraxia of speech usually involves the third frontal convolution i.e., the Broca's area of the dominant left hemisphere. However, it can also follow more posterior lesions. Some of the speech characteristics of apraxia of speech include articulatory groping behavior, facial grimaces, moments of silence, consonants more affected than vowels, inconsistent articulatory errors, articulatory errors are primarily substitutions, additions, and repetitions, temporal aspects of vowels and consonants are distorted, reduced speech rate, and alterations in intonation.

Assessment of motor speech disorders

The assessment of motor speech disorders can be done in 2 different ways – perceptually and/or using instruments.

Perceptual assessment

The different motor speech disorders including the dysarthrias and apraxias present different perceptual characteristics that can be judged using a number of dimensions. Some of the auditory perceptual categories for these dimensions include pitch loudness, voice quality, respiration, articulate, prosody. The judgements about these speech parameters about the adequacy are made usually according to rating scales. The advantages of perceptual assessments are manifold – the evaluations are carried out just on the basis of speech output, no specialized equipment other than the clinician's ears are required, and they serve as a standard by which intervention is assessed. The perceptual assessment comes with its own set of limitations with respect to factors such as experience of the person making judgements which affects reliability of evaluation. Another limitation of perceptual system is the limited analytic power for determining which aspects of speech motor patterning are affected e.g. the term 'imprecise consonants' does not identify whether a patient's speech is difficult to understand because of inaccurate tongue placement or because of inaccurate voice onset time for producing unvoiced consonants.

Instrumental assessment

The study of neurogenic speech disorders has frequently taken the form of acoustic analysis of spoken productions (Baum, Blumstein, Naeser, and Palumbo, 1990; Kent and Rosenbeck, 1983). Investigators have examined numerous aspects of aphasic and/ or apraxic speech, such as voice onset time (VOT), vowel duration (Baum et al., 1990), format trajectories (Kent & McNeil, 1987), fricative durations (Harmes, Daniloff, Hoffman, Lewis, Kramer, & Absher, 1984), and total word durations (McNeil, Liss, Tseng, & Kent, 1990). Wang, Kent, Duffy, and Thomas (2005) used acoustic analysis to examine speech rate and emphatic stress in individuals with dysarthria associated with traumatic brain injury. Previously, Ozsancak, Auzou, Jan, & Hannequin (2001) found the mean rate of measurable VOT of 95% for normal control speakers, 80% for individuals with hypokinetic dysarthria, and 84% for persons with spastic dysarthria. Whereas Schalling and Hartelius (2004) reported utility of acoustic analysis in distinguishing dysarthric speech from that of normal speech on the basis of various speech parameters such as speech rate, alternating motion rate, sequential motion rate, inter-stress interval. The instrumental assessment of motor speech disorders also includes physiological assessment tools such as kinematic analysis which measures information on the ongoing nature of neuromuscular movements. In some instances X-ray can also be used to localize and track the two dimensional movement of small gold pellets which are attached to the speech structure under study. Palatometry procedure consisting 96 tiny electrodes (0.5 mm each) embedded on the oral surface of an acrylic psuedopalate can be used to observe the pattern of tongue contact during speech production (Fletcher, 1972). In their study in children with Down syndrome, Wood, Wishart, Hardcastle, Cleland, and Timmins (2009) demonstrated utility of electropalatography in the assessment and treatment of motor speech disorders.

The Motor Speech Profile

As mentioned earlier, motor speech disorders can be typologically classified on the basis of speech symptoms, it is also possible that the underlying acoustic features of these symptoms present distinguishing features that would aid in identifying different types of motor speech disorders. One of the instruments that is useful for objective evaluation of motor speech disorders is The Motor Speech Profile (MSP), Model 4341, a module of the CSLTM- Computerized Speech Lab., model 4300B, (Kay Elemetrics

Corp.). The MSP constitutes built-in protocols for eliciting specific speech sample, extracts desired parameters, and displays results in numeric and graphic formats. The MSP measures various aspects of speech including voice, tremor, diadochokinesis, second formant transition, intonation, and syllabic rate. Several research studies used MSP in the diagnosis and differential diagnosiss of motor speech disorders. Previously, Lundy , Roy, Xue, Casiano, and Jassir (2004) used MSP to distinguish speech features in individuals with adductor spasmodic dysphonia, voice tremor, and spastic dysarthria of amyotrophic lateral sclerosis (ALS). The F0, DDK, and intensity profiles varied significantly across the 3 groups of individuals. Whereas Wang, Kent, Duffy, and Thomas (2008) evaluated reliability and concurrent validity of Diadochokinetic Rate Analysis (DRA) protocol of the MSP and hand measurement for individuals with ataxic dysarthria. They found adequate reliability and concurrent validity between different measuring methods. The MSP program can also be used to monitor progress in treatment of individuals with motor speech disorders. The effect of bilateral subthalamic nucleus (STN) stimulation and medication on hypokinetic parkinsonian dysarthria was studied by D'Alatri, Paludetti, Contarino, Galla, Marchese, and Bentivoglio (2008) using the Multidimensional Voice Program and the Advanced Motor Speech Profile.

REVIEW OF LITERATURE

The motor speech disorders are usually assessed behaviorally or objectively. The behavioral evaluation is referred to as perceptual assessment. The perceptual approach relies on the skills and expertise of the clinician in differentiating normal phenomenon from abnormal phenomenon. The approach was pioneered by Darley, Aronson, & Brown (1975). It is based on assumption that different motor speech disorders have different perceptual characteristics that can be judged on a number of dimensions. The auditory perceptual categories for these dimensions include pitch, loudness, voice quality, respiration, articulation, and prosody. The judgements are made usually according to rating scales. The advantages of perceptual approach are – judgements are made on the basis of speech output of the individual, requires no specialized equipment, and they can serve as a standard by which intervention is assessed. However relatively little work has been done to establish guidelines for the amount of experience needed to reliably rate dysarthric speech. Another limitation of perceptual system is the limited analytic power for determining which aspects of speech motor patterning are affected. For instance, the term 'imprecise consonant articulation' does not identify whether a patient's speech is difficult to understand because of inaccurate tongue placement or because of inaccurate voice onset time for producing unvoiced consonants. The following evaluation tasks rely on a clinician's perceptual analysis of a patient's speech.

Phonatory-respiratory system assessment

The 2 components of the speech mechanism are assessed at the same time because normal phonation depends on an adequate supply of subglottic air pressure tasks. One of the methods involves asking the patient to take a deep breath and say /a/ as long, steadily and clearly as possible. It evaluates both adequacy of breath support and vocal fold adduction for phonation. Too little breath support results in inadequate subglottic air pressure to prolong /a/ for more than 15 seconds. Whereas, increased latency between the signal to say /a/ and the initiation of phonation may reflect weakness of the phonatory respiratory system. In normal phonation vocal quality is steady, smooth, and clear. A certain amount of breathiness in voice indicates incomplete vocal fold adduction during phonation. Harshness is caused by the friction of air being passed through vocal folds that are almost adducted fully. The vocal pitch and loudness can be judged differently. For instance, pitch can be too low as in spastic dysarthria and hyperkinetic dysarthrias. Pitch breaks are heard most often in flaccid and spastic dysarthria. The involuntary movements in hyperkinetic dysarthria can cause excessive loudness variation during phonation. Poor respiratory support or inadequate phonation can cause decreased loudness which is most often seen in flaccid and hypokinetic dysarthria.

Resonatory system assessment

This is aimed at assessing the velopharyngeal function. The weakened/paralyzed velar muscle will result in perceived hypernasality. Hypernasality is most frequently a symptom of flaccid, spastic and hypokinetic dysarthria. Hyponasality is rarely present in dysarthric speech. Perceptually, resonance is evaluated by asking the patient to take a deep breath and say /u/ for as long as (s)he can. The high back vowel /u/ when prolonged usually maximizes velopharyngeal closure. As patient says /u/, clinician holds a small mirror first under one nostril and then under the other. Fogging of the mirror suggests presence of nasal emission. Alternately, squeezing and releasing of the nostrils while patient is producing /u/ allows to intermittently stop any nasal airflow during phonation. If there is hypernasality a difference will be heard in resonance as the patient's nose is squeezed and released.

Articulatory system assessment

The articulatory evaluation involves assessing production of speech sounds in isolation, word, and sentence level. Regional standardized tests are usually used to assess production of phonemes in regional languages. Apart from these, the alternate (AMR) and sequential motion rates (SMR) are used to tap articulatory coordination. The AMR & SMR provide valuable information on the speed and rhythm of syllable production. Individuals with different dysarthria types perform differently on this task.

Prosody assessment

Changes in loudness, pitch, duration, and pause time combine to yield the prosodic feature of intonation, stress, and rhythm. The diagnostic judgments can be made of spontaneous speech or a set of sentences to determine contrastive prosodic patterns. Rate of speech has been shown to be influenced by prosodic disturbances in motor speech disorders. For instance, the rate disturbance associated with Parkinson's disease can cause speech rate to be accelerated or slowed (Weismer, 1984).

Intelligibility assessment

Intelligibility is defined as the degree to which the acoustic signal is understood by the listener (Yorkson & Beukelman, 1981). Measures of intelligibility and comprehensibility are essential components of the assessment process because they are the means by which the acoustic signal is impeding communication (intelligibility) versus how well the individual is able to convey communication intent (comprehensibility) despite his/her degraded speech. The measurement of intelligibility and comprehensibility are important for providing baseline and outcome measurement data. The most common means of measuring intelligibility is to have a native listener orthographically transcribe what the child says from a tape recorder.

$$\text{Percentage intelligibility score} = \frac{\text{no of words correctly identified}}{\text{Total no. of words}}$$

Assessment of Intelligibility in Dysarthric Speakers (AIDS) (Yorkson & Beukelman, 1981) is a standardized test for measuring intelligibility, speaking rate and communicative efficiency in dysarthria. Measures of intelligibility and speaking rate are also included in Frenchay Dysarthria Assessment (FDA) (Enderby & Palmer, 2008). Intelligibility assessment includes intelligibility of words, sentences and conversation. The FDA demonstrates that distinctions among patients with different dysarthria types can be quantified and distinctions correlated with neurologic diagnosis. The test relies on patient report and rating of non-speech oral activities.

Instrumental assessment

The instrumental (acoustic or physiological) assessment has often been used to supplement perceptual methods to overcome some of the inherent limitations of subjective perceptual assessments (Collins, 1984). The acoustic analysis is a valuable complement to perceptual evaluation since it acts as confirmative tool (Kent, Weismer, Kent, Vorperian, & Duffy, 1999). The acoustic analysis provides data that can be tested for reliability of assessment and eliminates inter tester potential bias. The acoustic methods are related to auditory perceptual judgements of speech and contribute substantially to quantification, description, and understanding of motor speech disorders. The acoustic analysis makes the speech signal visible and provides baseline data that serves as an index of stability, improvement, or deterioration over time. It also serves as a source of feedback during therapy.

Concerning motor speech disorders, acoustic analysis can be helpful in the study of disturbed timing and sequencing. For instance speech tends to be slow, intermittent, and variable in apraxia of speech. Some of the acoustic characteristics which are seen in such cases include differences in word duration, much slower trajectory of second formant, longer productions, slow rates of acoustic changes, incoordination of voicing with oral articulatory function, variations in VOT (long interval of prevoicing) (Kent & Rosenbek, 1983). The influence of speaker sex, age, and race also needs to be considered in studies of voice disorder in dysarthria. Differences in voice characteristics between men and women were found in amyotrophic lateral sclerosis (Kent, Kim, Weismer, Kent, Rosenbek, Brooks, and Workinger, 1994 cited in Kent et al., 1999) and Parkinson's disease (Hertrich & Ackermann, 1995). Also, laryngeal and supralaryngeal function can be affected by aging (Linville, 2000; Weismer & Liss, 1991, cited in Kent et al., 1999). Since motor speech disorders such as dysarthria occur frequently in neurological diseases that are frequent in the elderly, the most appropriate normal control subjects in dysarthria research are older adults. Similarly, clinical evaluation should use age-appropriate normative standards. Some other studies reported influence of ethnic race in aspects of vocal function (Walton & Orlikoff, 1994, cited in Kent et al., 1999).

The study of neurogenic motor speech disorders has frequently taken the form of acoustic analysis of spoken productions (Kent et al., 1999). Ludlow, Coulter, and Gentges (1983) did not observe statistically significant difference in jitter between persons with Parkinson's disease and normal controls. Zwirner, Murry, and Woodson (1991, cited in Kent et al., 1999) reported that acoustic measures did not distinguish among three types of neurological disease namely Parkinson's disease, Huntington's disease, and cerebellar ataxia and neither these measures were different from normal controls (cited in Kent et al., 1999). Kent et al., (1994) (cited in Kent et al., 1999) too did not find significant differences in acoustic features of F0, jitter, shimmer, and signal-to-noise ratio between clinical and normal control groups (amyotrophic lateral sclerosis, Parkinson's disease, and cerebrovascular accident). Interestingly, Zwirner et al., (1991, cited in Kent et al., 1999) suggested long-term measures of phonatory instability like standard deviation of F0 hold greater potential than perturbation measures like jitter and shimmer. King, Ramig, Lemke, and Horii (1994) (cited in Kent et al., 1999) found similar long-term measures demonstrate significant linear declines in longitudinal studies of persons with Parkinson's disease. A complicating factor in the study of voice disorder is the heterogeneity of the impairment in persons with similar neurological classification.

Strand, Buder, Yorkston, and Ramig (1994, cited in Kent et al., 1999) reported differential phonatory characteristics in 4 women with amyotrophic lateral sclerosis (ALS) who had initial bulbar signs and progressive deterioration of phonation. Strand et al. (1994, cited in Kent et al., 1999) suggested if group data on dysarthria in ALS or other neurogenic speech disorders may mask the large variability among often seen in these persons. Further evidence of this variability was reported for stroke by Murdoch, Chenery, Stokes, & Hardcastle (1991, cited in Kent et al., 1999). Only about half of their subjects with upper motor neuron disease demonstrated hyperfunctional features such as elevated subglottal air pressure, increased glottal resistance, and decreased laryngeal airflow. The other half of their subjects presented with features of hypofunctional laryngeal activity.

Tremor observed in several neurological disorders is seen during task such as sustained phonation (vocal tremor). The tremor in both cerebellar disease and Parkinson's disease is relatively slow, in the range of about 3 to 7 Hz (Ackermann & Ziegler, 1991; Ludlow, Connor, & Bassich, 1987; cited in Kent et al., 1999). These tremor frequencies are low compared to either normal tremor or flutter that occurs in some persons with ALS. In a comparative study of 3 types of Parkinsonian syndromes, Penner, Miller, and Wolters (2007) conducted acoustic investigation of speech in progressive supranuclear palsy (PSP), multiple system atrophy (MSA) and idiopathic Parkinson's disease (IPD). While the IPD is characterized by hypokinetic dysarthria, the other 2 types exhibit characteristics of spastic and ataxic dysarthria along with features of hypokinetic dysarthria suggesting mixed dysarthria type. Four acoustic parameters (voice quality, pitch range, vowel space and alternating motion rate (AMR)) were investigated in 17 patients with PSP and 9 patients with MSA and compared with data from IPD patients. Participants with PSP and MSA performed significantly worse than the PD group on AMR tasks. In addition, the pitch range of PSP participants was restricted. These results demonstrated potential of acoustic analysis for early differential diagnosis of Parkinsonian syndromes. In examining phonation in PD speakers, Le Dorze, Ryalls, Brassard, Boulanger, and Ratte (1998) found no mean fundamental frequency (F0) differences between patients with PD and age-matched control speakers for a sentence reading task. While Doyle, Raade, St. Pierre, and Desai (1995) found F0 to be significantly higher for PD patients when measured during sustained vowel productions. Similar results were found for German-speaking males and females producing vowels Hertrich and Ackermann (1995), as well as for females producing Spanish vowels (Jimenez-Jimenez, Gamboa, Nieto, Guerrero, Orti-Pareja, Molina, Garcia-Albea, & Cobeta, 1997). Increased F0 has also been found in PD patients when speech was examined during reading passages and monologues (Canter, 1963; Holmes, Oates, Phyland, & Hughes, 2000; Metter & Hanson, 1986). Further, Metter and Hanson (1986) found that F0 continued to increase as severity of PD increased. The increased F0 in PD patients is generally attributed to rigidity of the laryngeal musculature, which results in increased stiffness of the vocal folds.

Several researchers found increased F0 range and variability in PD patients compared to normal speakers (Doyle, Raade, St. Pierre, & Desai, 1995; Hertrich & Ackermann, 1995); Jimenez-Jimenez et al., 1997; Kent et al., 1994; Zwirner & Barnes 1992). In prolonged vowels, Doyle et al., (1995) found increased F0 range for PD females, and no difference in range for males. Zwirner and Barnes (1995) found increased standard deviation of F0 for person with PD in prolonged vowels. Similarly, increased jitter was found in prolonged vowel production (Hertrich & Ackermann, 1995; Jimenez-Jimenez et al., 1997; Kent et al., 1994). The increased F0 range and its variability was suggested to result from impaired ability to exert control over laryngeal muscles during sustained vowel production. Others examined intensity range and ability to vary intensity as a measure of respiratory function in persons with PD. Compared to control speakers, PD speakers were found to present overall lower intensity levels (Countryman & Ramig, 1993; Holmes et al., 2000; Ramig, Sapir, Fox, & Countryman, 2001), deficits in maintaining intensity levels (Ho, Iansek, & Bradshaw, 2001), and deficits regulating intensity in response to external cues (Ho, Bradshaw, Iansek, & Alfredson, 1999). Further, Canter (1965) found that, when asked to repeat a syllable at four different loudness levels, persons with PD produced smaller intensity range than normal control speakers. The deficits in intensity range and control suggest persons with PD patients may exhibit decreased breath support and control for speech.

The vowel articulation is usually represented acoustically by the first few formant frequencies (F1, F2, F3). It is important to consider subject characteristics like age, sex, among others form making judgments about formant frequencies since formant frequencies vary with the length of the speaker's vocal tract. The most frequently reported abnormalities of vowel production in dysarthria include: centralization of formant frequencies (Ziegler & von Cramon, 1983, 1986, cited in Kent et al., 1999), and abnormal formant frequencies for high vowels and front vowels (Watanabe, Arasaki, Nagata, & Shouji, 1994, cited in Kent et al., 1999). Formant-frequency fluctuation is a variability in formant pattern in sustained vowel phonation or other vowel steady states

(Robb, Blomgren, & Chen, 1998, cited in Kent et al., 1999). This fluctuation can be used to document involuntary vocal tract movements in disorders such as tremor, chorea, or dystonia.

Acoustic correlates of prosodic features like intonation, rhythm, among others have also been used to describe speech of persons with dysarthria. Le Dorze, Ryalls, Brassard, Boulanger and Ratte (1998) examined F0 differences in 20 question-statement pairs produced in the speakers' native French language. They compared the F0 of the last syllable in each sentence and found that the 10 PD patients produced significantly smaller F0 differences compared to age-matched normal speakers. While the normal speakers produced the questions with higher F0 on the last syllable, persons with PD did not produce this F0 difference. Earlier, Le Dorze, Ouellet, and Ryalls (1994) investigated various types of dysarthria including hypokinetic dysarthria, and found similar low mean F0 difference for question-statement pairs produced by dysarthric speakers. Darkins, Fromkin, and Benson (1988) examined F0 declination 30 persons with PD and age-matched normal speakers. Normal speakers produced a significant frequency declination in the second word of compound nouns, and not in the second word of noun phrases. However, persons with PD did not make this distinction, as there was no difference in frequency between noun phrases and compound nouns. Metter and Hanson (1986, cited in Kent et al., 1999) examined F0 variability in a reading passage and found a significant decrease in F0 variability compared to normal speakers. This variability decreased further as severity of PD increased. More recently, Jimenez-Jimenez et al., (1997, cited in Kent et al., 1999) also found decreased F0 variability in sentence productions of untreated PD patients. Normal speakers typically demonstrate a high F0 range and variability during reading tasks, corresponding with normal rising and falling intonations during speech. A decrease in F0 variation during reading tasks may reflect a prosodic deficit.

Deliyski and Gress (1997) obtained normative data in healthy male and female subjects (age range: 18-60 years) using the Motor Speech Profile (MSP) Model 4341. The results indicated significant male/female differences for a number of parameters including measures of F0 and second formant characteristics. These differences were on expected lines due to the typical male/female structural features of the larynx and the vocal tract. There was no significant correlation between any parameter and subjects' age. The results also revealed high intra- and inter-judge reliability. Wheras, Wong, Allegro, Tirado, Chadha, and Campisi (2011) obtained MSP normative data in children aged 4-18 years. They found age-dependent changes in the form of increase in average diadochokinetic rate and standard syllabic duration with age. However, no significant differences were found between males and females for any motor speech characteristic. Also, variations in fundamental frequency (F0) during speech did not change significantly with age for both males and females. The Diadochokinetic Rate Analysis (DRA) protocol of the MSP measures the rate and regularity of consonant-vowel (CV) syllables repeated in a task involving maximum-rate repetition on one deep breath. The DRA protocol generates 11 temporal and intensity parameters automatically and simultaneously. Padovani, Gielow and Behlau (2009) analyzed the DDK rate in healthy subjects of 2 groups using MSP software (KayPENTAX, Lincoln Park, NJ). Group-1 consisted of 14 females and 9 males, aged between 30 and 46 years and group-2 included 14 females and 9 males, aged between 47 and 94 years. The results revealed that rate changes according to syllable produced and it reduces as the articulatory point goes backward. The rate variation did not significantly vary with age; however the intensity peak had great variation in all tasks for the elderly adults. While, Wang et al., (2004) evaluated DDK of the MSP to measure suitability, reliability, and concurrent validity in 21 individuals with ataxic dysarthria. The results revealed that more than one third of the DDK samples were nonexecutable, the reliability at different thresholds and concurrent validity between different measuring methods were both satisfactory, and temporal variation parameters were more inconsistent between different measuring methods than intensity variation parameters.

The study by Lundy, Roy, Xue, Casiano, and Jassir (2004) determined if vocal qualities of neurologic origin could be differentiated on the basis of acoustic and motor speech parameters. Three groups of subjects (ADSD, ALS, and Tremor) were analyzed by the Motor Speech Profile System (MSP) (Kay Elemetrics, Lincoln Park, NJ) for F0, standard deviation of F0, diadochokinetic rate (DDK), standard deviation of DDK, mean intensity and standard deviation of DDK, frequency and amplitude variability in connected speech, and speaking rate in connected speech. The resulting profiles of the three groups significant features that differentiated one from the other. The MSP software has also been used to study treatment efficacy. D'Alatri, Paludetti, Contarino, Galla, Marchese, and Bentivoglio (2008) used combination of Multidimensional Voice Program and the Advanced MSP (Kay Elemetrics, Lincoln Park, NJ) to determine impact of bilateral subthalamic nucleus (STN) stimulation and medication on hypokinetic parkinsonian dysarthria. The results revealed none of the evaluated parameters deteriorated after STN deep brain stimulation. STN stimulation significantly improved motor performances and provided stability to glottal vibration. In another study, Xie, Zhang, Zheng, Liu, Wang, Zhuang, Li, and Wang (2010) investigated the effects of bilateral subthalamic nucleus deep brain stimulation (STN-DBS) on acoustic characteristics of speech in Chinese persons with PD using Multidimensional Voice Program (MDVP), the Motor Speech Profile (MSP), and Computerized Speech Lab (CSL) (Kay Elemetrics, Lincoln Park, NJ). Although the patients' motor ability improved, no changes in speech quality were reflected on any of the acoustic measures.

The previous studies unequivocally suggest the application of objective acoustic measurements in clinical description and evaluation of persons with neurogenic speech motor disorders. The data from these instrumental acoustic analyses provides important information in diagnosis and differential diagnosis of various motor speech disorders. The data also provides baseline measurement which can be used as a reference for determining treatment efficacy using any given therapeutic technique. The studies also emphasized the important role of MSP software. However, the normative data of the studies carried out in foreign population cannot be used for evaluating Indian population since the voice and speech profile is well known to be influenced by ethnicity. There is a need to develop parametric profile of MSP that can be used in Indian context.

Aim

To develop normative data in adults for the various parameters of the Motor Speech Profile, for use in clinical and research applications.

Objectives

a) To compare parameters of the Motor Speech Profile across the different age groups of adults.

b) To compare parameters of the Motor Speech Profile with respect to gender.

METHOD

Participants

The participants included were adults who did not present any signs and symptoms of speech and language problems and those who had no professional training in singing. The participants were divided into 4 different groups based on age (n=100 per group): 20-30 years, 30-40 years, 40-50 years, and 50-60 years. The groups comprised equal number of males and females i.e., 50 males and 50 females in each group. The participants were perceptually assessed for establishing normal voice quality using the GRBAS scale, which stands for grade, roughness, breathiness, asthenicity, and strain. Participants with ratings higher than 0, even if it was on one measure, will be excluded. The speech intelligibility rating scale also be administered for perceptual assessment of overall speech quality. Individuals with rating of '0' i.e., no speech abnormality were selected for the study. The participants were screened for misarticulations at all levels of linguistic structure – isolation, word, sentence, and discourse. The Telugu Test of Articulation and Phonology (Vasanta, 1990) was administered for each participant. Individuals with no misarticulations at all linguistic levels were selected for the study. The perceptual ratings were carried out by 3 experienced speech-language pathologists.

Exclusionary criteria for participants:

- Persons with history of neurological (aphasia, dysarthria, apraxia of speech, among others) problem.

- Persons with hearing problem. The hearing evaluation was carried out using pure tone audiometry. Individuals with hearing status of less than 25 dB of pure tone average (PTA) were considered for the study.
- Person who had h/o speech/voice problems were not considered for the study.

Protocol for obtaining data

Extensive analysis programs are included for all aspects of motor speech analysis. Each protocol provides the participant with the appropriate verbal prompts and examples. The protocol automates the acquisition, analysis, and graphical reporting to facilitate quick and easy implementation of these tests.

1) Voice and Tremor Protocol

Sustain the vowel "a" for at least five seconds.

2) Diadochokenetic Rate Protocol

Repeat the syllable "pa" as quickly as possible for eight seconds.

3) Second Formant Transition Protocol

Repeat "ee-u" as quickly as possible for six seconds.

Modification:

Repeat "a-ee" as quickly as possible for six seconds.

4) Intonation Stimulability Protocol

Say the sentence: "Are you leaving today or tomorrow?" in Telugu as “/miru bail derutundi i rodʒa leda repa/”

5) Standard Syllabic Rate Protocol

Say the sentence: "We knew you were away all year." in Telugu as “/miru səməsrəmənta durəɳa unnarəni maku telusu/

Recording

The data was recorded individually in the speech laboratory using the company prescribed microphone for CSL software. The microphone was placed at a distance of about 10 cms from the mouth. The data was recorded in a quiet environment for the parameters in Motor Speech Profile. Four seconds voice sample was selected by trimming few milliseconds in the initial and the final position of the recorded samples. The MSP analysis was then performed, and the acoustic voice variables were displayed.

The parameters of MSP that were studied are given below. The DDK, second formant transition, voice, intonation, and syllabic rate parameters form important and dynamic speech production aspects. The previous research related to neurogenic motor speech disorders clearly suggested the sensitivity of these aforementioned acoustic parameters in characterizing abnormal speech production in such individuals. The DDK requires integrity of several speech musculature that need to work in coordinated and unison manner for sustained articulation of series of syllables. The MSP captures specific aspects of DDK such as period, rate, perturbation/variations in period, intensity. The vowel quality is largely impacted by second formant transition. The role of second formant in distinguishing vowels and in coarticulation is well documented. The MSP measures the F2 formant value, rate and magnitude of F2 variation. The voice profile of MSP captures important vocal aspects such as frequency, intensity, perturbations such as jitter, shimmer. These are invariably affected in several types of neurogenic speech disorders. The physiological variations in speech production are reflected by tremors. The MSP addresses aspects of tremors in the domain of rate, magnitude and periodicity of tremors. Closely related to voice production are the F0 variations in speech that enhance semantic/syntactic profile of an utterance. The intonation parameters of MSP address issues related to F0 range, variations in F0 and amplitude during speech production. Persons with motor speech disorders vary their speech rate considerably than healthy persons. They tend to insert pauses that may be longer than expected. The MSP provides analysis of speech rate in terms of syllabic rate, syllable duration, pause duration, and percent speaking time.

Acoustic Variables	**Symbol**
Diadochokinetic Rate Parameters	
1) Average DDK Period	DDKavp, ms
2) Average DDK Rate	DDKavr, /s
3) Standard Deviation of DDK Period	DDKsdp, ms
4) Coefficient of Variation of DDK Period	DDKcvp, %
5) Perturbation of DDK Period	DDKjit, %
6) Average DDK Peak Intensity	DDKavi, dB
7) Standard Deviation of DDK Peak Intensity	DDKsdi, dB
8) Coefficient Variation of DDK Peak Intensity	DDKcvi, %
9) Maximum Intensity of DDK Sample	DDKmxa, dB
10) Average Intensity of DDK Sample	DDKava, dB
11) Average Syllabic Intensity	DDKsla, dB

Second Formant Transition Parameters	
1) Magnitude of F2 variation	F2magn, Hz
2) Rate of F2 Variation	F2rate, /s
3) Regularity of F2 Variation	F2reg, %
4) Average of F2 Value	F2aver, Hz
5) Minimum F2 Value	F2min, Hz
6) Maximum F2 Value	F2max, Hz
Voice Parameters	
1) Average Fundamental Frequency	(F0) in Hz
2) Average Pitch Period	(T0) ms
3) Highest Fundamental Frequency	(Fhi) in Hz
4) Lowest Fundamental Frequency	(Flo) in Hz
5) Standard Deviation of Fundamental Frequency	(STD) in Hz
6) Coefficient of Variation of Fundamental Frequency	(vFo) in %
7) Coefficient of Variation of Amplitude	(vAm) in %
Tremor Parameters	
1) Magnitude Frequency Tremor	Mftr, %
2) Magnitude Amplitude Tremor	Matr, %
3) Rate of Frequency Tremor	Rftr, Hz
4) Rate of Amplitude Tremor	Ratr, Hz
5) Periodicity of Frequency Tremor	Pftr, %
6) Periodicity of Amplitude Tremor	Patr, %
Intonation Stimulability Parameters	

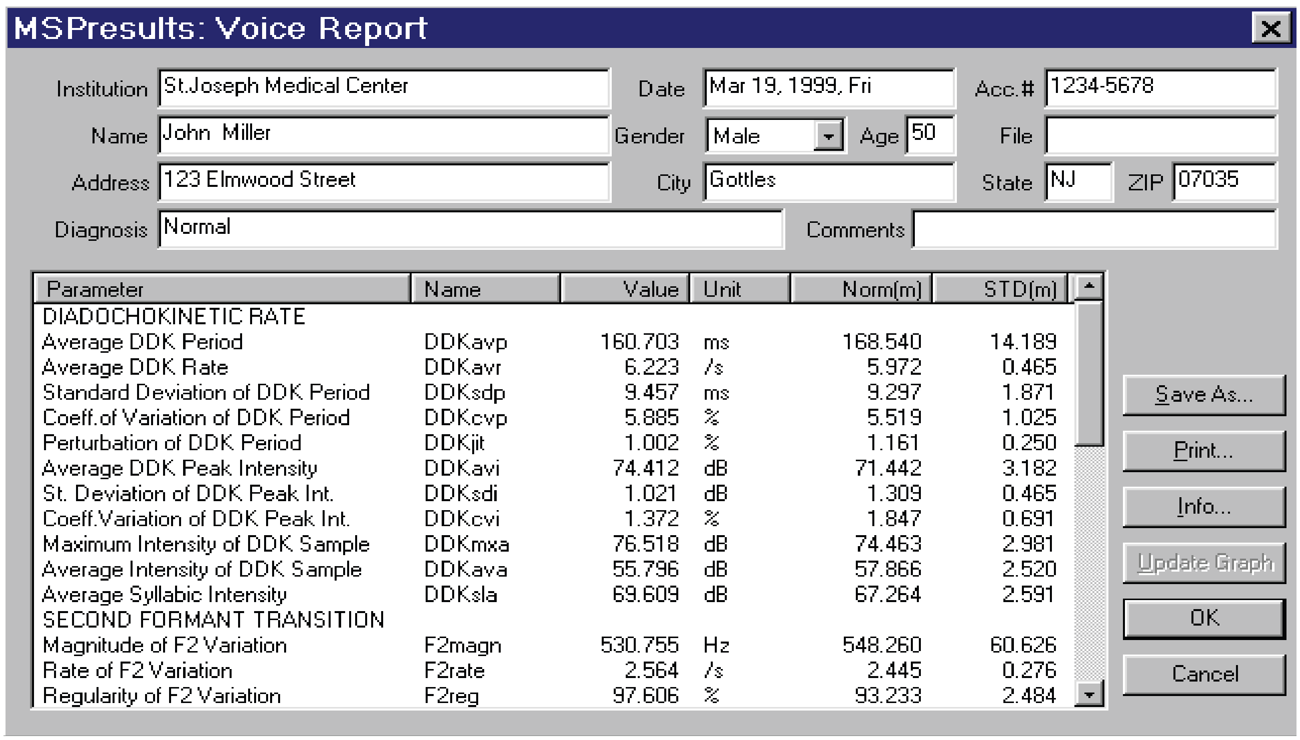
1) Running Speech Fund. Frequency	rFo, Hz
2) Running Speech Pitch Period	rTo, ms
3) Highest Fundamental Frequency	rFhi , Hz
4) Lowest Fundamental Frequency	rFlo, Hz
5) Standard Deviation of Fundamental Frequency	rSTD, Hz
6) Frequency Variability	rvFo, %
7) Amplitude Variability	rvAm, %
Syllabic Rate Parameters	
1) Average Syllabic Rate	SLrate, /s
2) Average Syllabic Duration	SLsdur, ms
3) Average Pause Duration	SLpdur, ms
4) Percent Speaking Time	SLspk, %
5) Percent Pause Time	SLpau, %

Reporting

The analysis of all the parameters (Diadochokinetic Rate Parameters, Second Formant Transition Parameters, Voice Parameters, Tremor Parameters, Intonation Stimulability Parameters, and Syllabic Rate Parameters) were done using motor speech profile and the values were obtained for different age groups which are taken in the project. MSP summarizes the numerical results and presents them as a report so that changes over time can be more easily examined. This report includes a graphic analysis with the patient's results plotted against normal values so that the examiner can quickly see how a patient compares.

Motor Speech Profile "exercises" and tests a subject's motor speech functions. It provides easy-to-use, built-in protocols and sophisticated analysis algorithms to produce comprehensive reports including graphic displays and numerical analysis.

Fig 1: Sample format of MSP numerical results.



MSPresults: Voice Report

Institution: St.Joseph Medical Center | Date: Mar 19, 1999, Fri | Acc.#: 1234-5678

Name: John Miller | Gender: Male | Age: 50 | File:

Address: 123 Elmwood Street | City: Gottles | State: NJ | ZIP: 07035

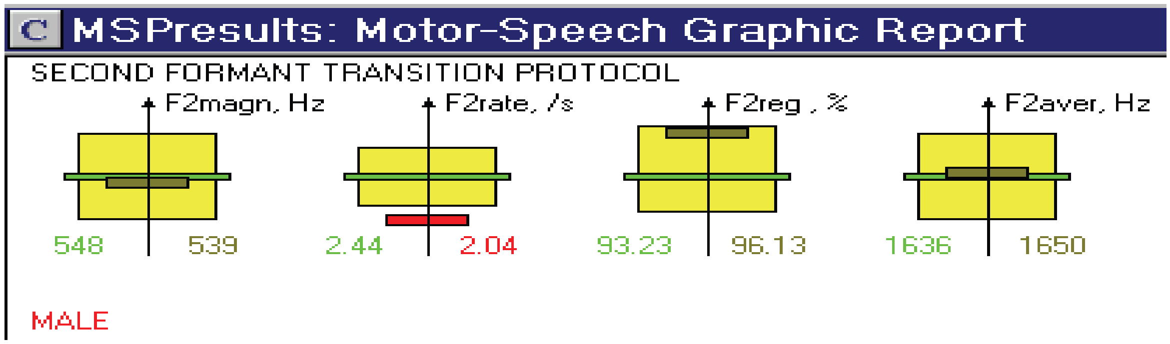
Diagnosis: Normal | Comments:

Parameter	Name	Value	Unit	Norm(m)	STD(m)
DIADOCHOKINETIC RATE					
Average DDK Period	DDKavp	160.703	ms	168.540	14.189
Average DDK Rate	DDKavr	6.223	/s	5.972	0.465
Standard Deviation of DDK Period	DDKsdp	9.457	ms	9.297	1.871
Coeff.of Variation of DDK Period	DDKcvp	5.885	%	5.519	1.025
Perturbation of DDK Period	DDKjit	1.002	%	1.161	0.250
Average DDK Peak Intensity	DDKavi	74.412	dB	71.442	3.182
St. Deviation of DDK Peak Int.	DDKsdi	1.021	dB	1.309	0.465
Coeff.Variation of DDK Peak Int.	DDKcvi	1.372	%	1.847	0.691
Maximum Intensity of DDK Sample	DDKmxa	76.518	dB	74.463	2.981
Average Intensity of DDK Sample	DDKava	55.796	dB	57.866	2.520
Average Syllabic Intensity	DDKsla	69.609	dB	67.264	2.591
SECOND FORMANT TRANSITION					
Magnitude of F2 Variation	F2magn	530.755	Hz	548.260	60.626
Rate of F2 Variation	F2rate	2.564	/s	2.445	0.276
Regularity of F2 Variation	F2reg	97.606	%	93.233	2.484

Save As... | Print... | Info... | Update Graph | OK | Cancel

The Motor Speech Profile generates a comprehensive report in both numerical and graphic format. The Figure1 shows DDK and Second Formant Transition analysis with norms and STD in numerical format. The numbers and the graphic comparison to the database of normals are generally printed in a report as given in Figure 2.

Fig 2: Sample graphical format of MSP results.



The protocols yield a graph of the subject's performance. The yellow area is ±1 STD. The olive line shows results within 1 STD and the red line shows results outside 1 STD. Numerical results for average norm and subject's extracted parameter are also displayed. This protocol, for Second Formant Analysis, is very revealing of many motor speech problems.

Statistical analysis

The statistical analysis was done using SPSS 17.0 software. The descriptive statistics including mean, standard deviation, and confidence intervals of all parameters obtained for all subgroups. The Independent Samples T-test was used to test significance of difference in mean across gender. The One-way ANOVA was used to test the significance of difference in mean across different age groups.

RESULTS

Diadochokinetic Rate Parameters

1. Average DDK Period (DDK avp) (ms)

The results for DDKavp are presented in Table 1 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	214.31	238.35	75.34	160.43	123.57	111.54	443.00	940.76	319.43	829.22
30-40	226.78	230.67	138.25	110.75	124.36	115.21	833.75	561.04	709.39	445.84
40-50	199.82	290.76	85.84	220.70	109.32	35.04	700.43	982.28	591.11	947.24
50-60	219.14	268.32	113.34	173.95	109.32	86.33	698.15	982.15	588.83	895.82

The mean DDK avp for males in the age group of 20-30 years was found to be 214.31 (SD = 75.34) whereas in females it was 238.35 (SD = 160.43). The range of DDK avp in males was observed as 319.43 and in females it was 829.22. The minimum DDK avp in males was 123.57 and in females it was 111.54. The maximum DDK avp in males was 443.00 and 940.76 in females. The mean DDK avp for males in the age group of 30-40 years was found to be 226.78 (SD = 138.25) whereas in females it was 230.67 (SD = 110.75). The range of DDK avp in males was observed as 709.39 and in females it was 445.84. The minimum DDK avp in males was 124.36 and in females it was 115.21. The maximum DDK avp in males was 833.75 and 561.04 in females. The mean DDK avp for males in the age group of 40-50 years was found to be 199.82 (SD = 85.84) whereas in females it was 290.76 (SD = 220.70). The range of DDK avp in males was observed as 591.11 and in females it was 947.24. The minimum DDK avp in males was 109.32 and in females it was 35.04. The maximum DDK avp in males was 700.43 and 982.28 in females. The mean DDK avp for males in the age group of 50-60 years was found to be 219.14 (SD = 113.34) whereas in females it was 268.32 (SD = 173.95). The range of

DDK avp in males was observed as 588.83 and in females it was 895.82. The minimum DDK avp in males was 109.32 and in females it was 86.33. The maximum DDK avp in males was 698.15 and 982.15 in females. The One-way ANOVA between the different groups in females did not reveal significant difference ($F(3, 191) = 1.288$, $p < .280$). Similarly no significant difference was observed across different age groups in males too ($F(3,192) = .562$, $p < .641$). The independent t-test between the females (M=262.1, SD=182.53) and males (M=246.1, SD=205) did not reveal significant difference t(389)=.82, p=.42. The results seem to suggest no effect of either age or gender concerning DDK avp.

Fig 3: Average DDK Period of males for age groups between 20-60 years

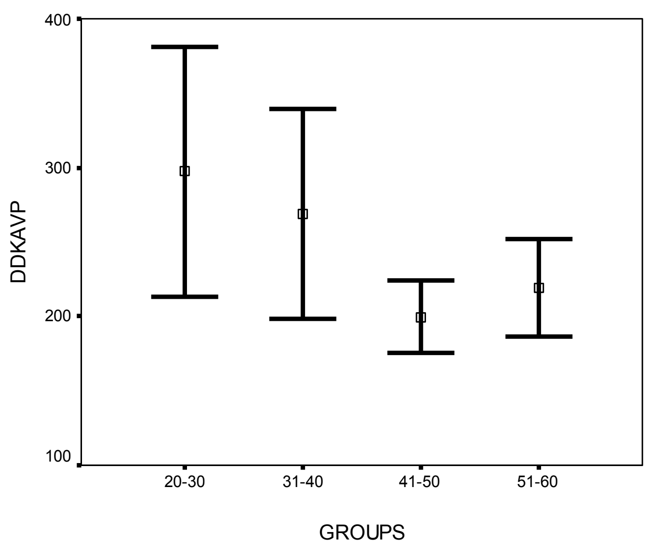
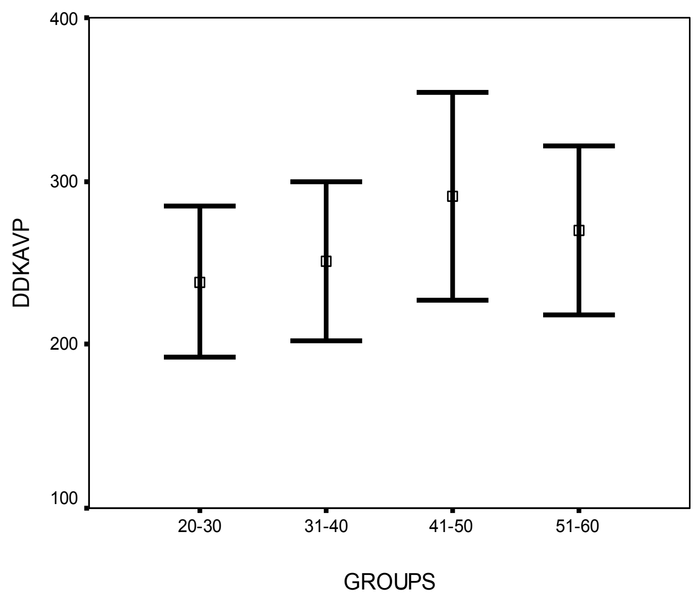


Fig 4: Average DDK Period of females for age groups between 20-60 years



2. Average DDK Rate (DDK avr) (/s)

The results for DDK avr are presented in Table 2 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	4.68	5.23	1.80	1.93	.56	1.06	7.49	8.97	6.92	7.90
30-40	5.05	4.98	1.74	1.88	.79	.89	8.04	8.68	7.25	7.79
40-50	5.38	5.00	1.43	3.90	1.33	1.02	9.15	28.54	7.82	27.52
50-60	5.28	4.67	1.58	1.89	1.43	1.02	9.15	11.58	7.72	10.57

The mean DDK avr for males in the age group of 20-30 years was found to be 4.68 (SD = 1.80) whereas in females it was 5.23 (SD = 1.93). The range of DDK avr in males was observed as 6.92 and in females it was 7.90. The minimum DDK avr in males was .56 and in females it was 1.06. The maximum DDK avr in males was 7.49 and 8.97 in females. The mean DDK avr for males in the age group of 30-40 years was found to be 5.05 (SD = 1.74) whereas in females it was 4.98 (SD = 1.88). The range of DDK avr in males was observed as 7.25 and in females it was 7.79. The minimum DDK avr in males was 0.79 and in females it was 0.89. The maximum DDK avr in males was 8.04 and 8.68 in females. The mean DDK avr for males in the age group of 40-50 years was found to be 5.38 (SD = 1.43) whereas in females it was 5 (SD = 3.90). The range of DDK avr in males was observed as 7.82 and in females it was 27.52. The minimum DDK avr in males was 1.33 and in females it was 1.02. The maximum DDK avr in males was 9.15 and 28.54 in females. The mean DDK avr for males in the age group of 50-60 years was found to be 5.28 (SD = 1.58) whereas in females it was 4.67 (SD = 1.89). The range of DDK avr in males was observed as 7.72 and in females it was 10.57. The minimum DDK avr in males was 1.43 and in females it was 1.02. The maximum DDK avr in males was 9.15 and 11.58 in females. The One-way ANOVA did not reveal significant main effect of age in females ($F(3,191) = .386$, $p < .763$) and males ($F(3,192) = 1.,\ 729$, $p < .163$). The independent t-test between the females (M=4.97, SD=2.54) and males (M=5.1, SD=1.65) did not reveal significant difference t(389)= -0.58, p=.559. The results do not reveal any impact of age or gender with respect to DDK avr.

Fig 5: Average DDK Rate of males for age groups between 20-60 years

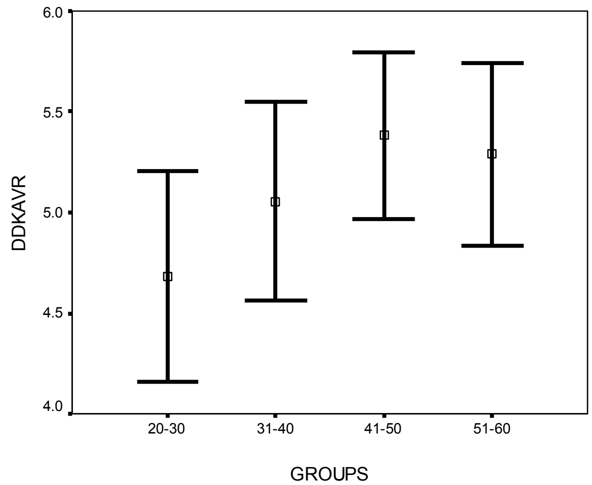
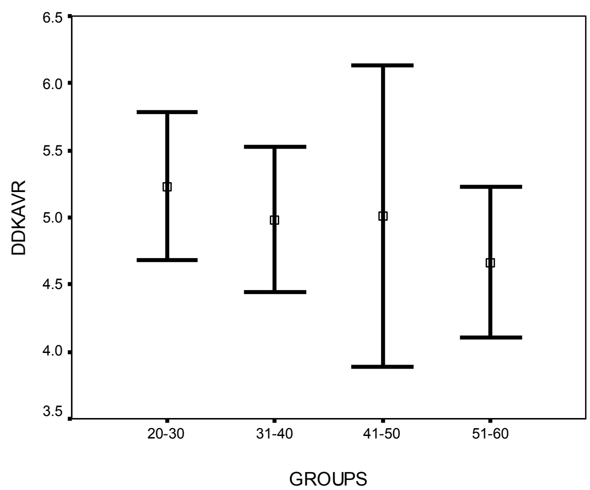


Fig 6: Average DDK Rate of females for age groups between 20-60 years



3. Standard Deviation of DDK Period (DDKsdp) (ms)

The results for DDK sdp are presented in Table 3 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	125.76	230.04	70.43	90.74	10.22	93.74	351.43	395.56	341.22	301.82
30-40	116.98	51.73	114.06	25.79	13.47	9.60	499.41	98.63	485.94	89.03
40-50	54.68	286.3	31.88	423.5	12.7	.00	203.5	176.9	190.7	176.9

		2		9	9		4	6	5	6
50-60	61.75	152.8 5	64.35	158.8 0	11.4 6	27.87	416.4 2	998.8 4	404.9 6	970.9 6

The mean DDK sdp for males in the age group of 20-30 years was found to be 125.76 (SD = 70.43) whereas in females it was 230.04 (SD = 90.74). The range of DDK sdp in males was observed as 341.22 and in females it was 301.82. The minimum DDK sdp in males was 10.22 and in females it was 93.74. The maximum DDK sdp in males was 351.43 and 395.56 in females. The mean DDK sdp for males in the age group of 30-40 years was found to be 116.98 (SD = 114.06) whereas in females it was 51.73 (SD = 25.79). The range of DDK sdp in males was observed as 485.94 and in females it was 89.03. The minimum DDK sdp in males was 13.47 and in females it was 9.60. The maximum DDK sdp in males was 499.41 and 98.63 in females. The mean DDK sdp for males in the age group of 40-50 years was found to be 54.68 (SD = 31.88) whereas in females it was 286.32 (SD = 423.59). The range of DDK sdp in males was observed as 190.75 and in females it was 176.96. The minimum DDK sdp in males was 12.79 and in females it was 0.00. The maximum DDK sdp in males was 203.54 and 176.96 in females. The mean DDK sdp for males in the age group of 50-60 years was found to be 61.75 (SD = 64.35) whereas in females it was 152. 85 (SD = 158.80). The range of DDK sdp in males was observed as 404.96 and in females it was 970.96. The minimum DDK sdp in males was 11.46 and in females it was 27.87. The maximum DDK sdp in males was 416.42 and 998.84 in females. The One-way ANOVA across the different age groups revealed significant main effect in both females ($F(3,191) = 9.630$, $p < .000$) and males ($F(3,191) = 11.131$, $p < .000$). The independent t-test between the females (M=216.63, SD=295.63) and males (M=187.54, SD=303.34) did not reveal significant difference t(385)=.95, *p*=.34. The results suggest impact of age in both females and males concerning DDK sdp where as gender has no influence with respect to the same parameter.

Fig 7: Standard Deviation of DDK Period of males for age groups between 20-60 years

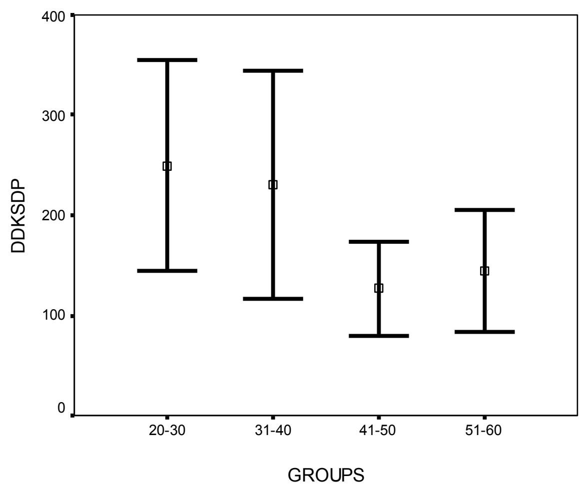
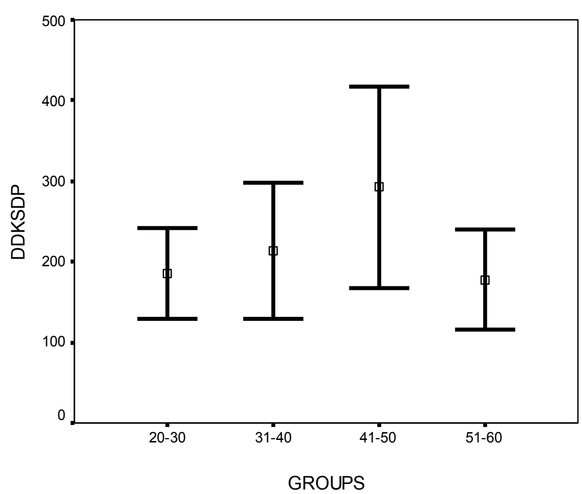


Fig 8: Standard Deviation of DDK Period of females for age groups between 20-60 years



4. Coefficient of Variation of DDK Period (DDK cvp) (%)

The results for DDK cvp are presented in Table 4 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	49.65	67.24	25.80	25.98	4.04	6.68	90.85	128.28	86.81	121.60
30-40	61.52	67.81	45.07	48.62	14.86	5.10	196.14	279.29	181.28	274.19
40-50	39.64	72.92	20.36	44.74	10.74	.00	92.31	180.19	81.57	180.19
50-60	38.35	50.35	21.88	28.93	8.72	1.62	97.31	121.79	88.59	120.16

The mean DDK cvp for males in the age group of 20-30 years was found to be 49.65 (SD = 25.80) whereas in females it was 67.24 (SD = 25.98). The range of DDK cvp in males was observed as 86.81and in females it was 121.60. The minimum DDK cvp in males was 4.04 and in females it was 6.68. The maximum DDK cvp in males was 90.85 and 128.28 in females. The mean DDK cvp for males in the age group of 30-40 years was found to be 61.52 (SD = 45.07) whereas in females it was 67.81 (SD = 48.62). The range of DDK cvp in males was observed as 181.28 and in females it was 274.19. The minimum DDK cvp in males was 14.86 and in females it was 5.10. The maximum DDK cvp in males was 196.14 and 279.29 in females. The mean DDK cvp for males in the age group of 40-50 years was found to be 39.64 (SD = 20.36) whereas in females it was 72.92 (SD = 44.74). The range of DDK cvp in males was observed as 81.57 and in females it was 180.19. The minimum DDK cvp in males was 10.74 and in females it was 0.00. The maximum DDK cvp in males was 92.31 and 180.19 in females. The mean DDK cvp for males in the age group of 50-60 years was found to be 38.35 (SD = 21.88) whereas in females it was 50.35 (SD = 28.93). The range of DDK cvp in males was observed as 88.59 and in females it was 120.16. The minimum DDK cvp in males was 8.72 and in females it was 1.62. The maximum DDK cvp in males was 97.31and 121.79 in females. There was significant main effect of age observed for both females ($F(3,190) = 3.364$, $p < .020$) and males ($F(3,190) = 6.277$, $p < .000$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=67.5, SD=40.4) and males (M=59.4, SD=45) did not reveal significant difference t(385)=1.9, p=.63. The results suggest influence of age in both females and males while no such influence of gender was observed with respect to DDK cvp.

Fig 9: Coefficient of Variation of DDK Period of males for age groups between 20-60 years

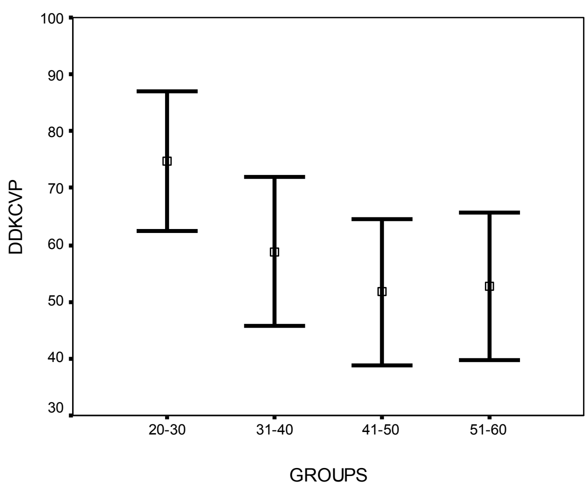
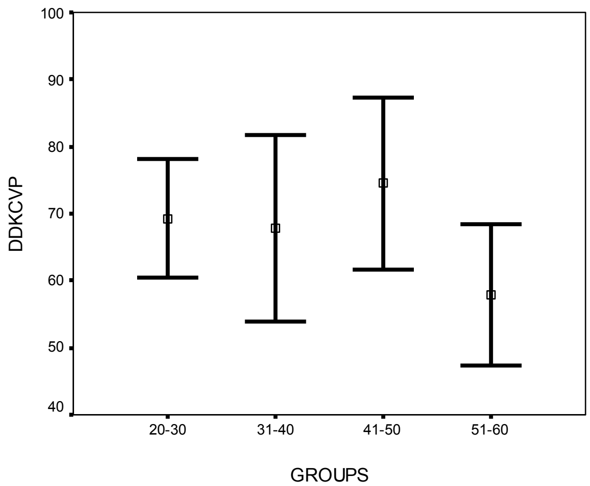


Fig 10: Coefficient of Variation of DDK Period of females for age groups between 20-60 years



5. Perturbation of DDK Period (DDK jit) (%)

The results for DDK jit are presented in Table 5 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	19.96	17.36	22.07	16.09	1.07	1.30	100.02	72.74	98.95	71.44
30-40	10.59	15.04	12.62	15.21	1.79	1.22	60.69	63.67	58.90	62.45
40-50	10.43	28.11	15.48	47.65	1.30	.00	80.99	216.25	79.69	216.25
50-60	10.39	16.92	10.72	23.55	1.94	1.17	46.31	136.93	44.37	135.76

The mean DDK jit for males in the age group of 20-30 years was found to be 19.96 (SD = 22.07) whereas in females it was 17.36 (SD = 16.09). The range of DDK jit in males was observed as 98.95 and in females it was 71.44. The minimum DDK jit in males was 1.07 and in females it was 1.30. The maximum DDK jit in males was 100.02 and 72.74 in females. The mean DDK jit for males in the age group of 30-40 years was found to be 10.59 (SD = 12.62) whereas in females it was 15.04 (SD = 15.21). The range of DDK jit in males was observed as 58.90 and in females it was 62.45. The minimum DDK jit in males was 1.79 and in females it was 1.22. The maximum DDK jit in males was 60.69 and 63.67 in females. The mean DDK jit for males in the age group of 40-50 years was found to be 10.43 (SD = 15.48) whereas in females it was 28.11 (SD = 47.65). The range of DDK jit in males was observed as 79.69 and in females it was 216.25. The minimum DDK jit in males was 1.30 and in females it was .00. The maximum DDK jit in males was 80.99 and 216.25 in females. The mean DDK jit for males in the age group of 50-60 years was found to be 10.39 (SD = 10.72) whereas in females it was 16.92 (SD = 23.55). The range of DDK jit in males was observed as 44.37 and in females it was 135.76. The minimum DDK jit in males was 1.94 and in females it was 1.17. The maximum DDK jit in males was 46.31 and 136.93 in females. The One-way ANOVA did not reveal significant difference between the different age groups in females ($F(3,190) = 2.118$, $p < .099$) but the results were contrary in males where significant difference was observed ($F(3,190) = 4.327$, $p < .006$). The independent t-test between the females (M=20.52, SD=32.86) and males (M=17.02, SD=39.91) did not reveal significant difference $t(385)=0.94$, $p=.34$

Fig 11: Perturbation of DDK Period of males for age groups between 20-60 years

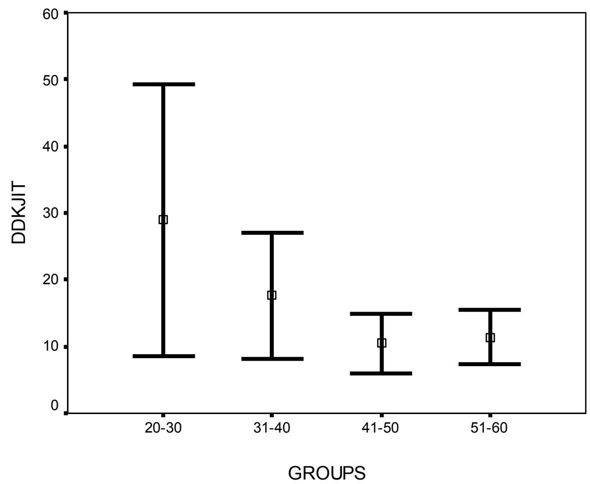
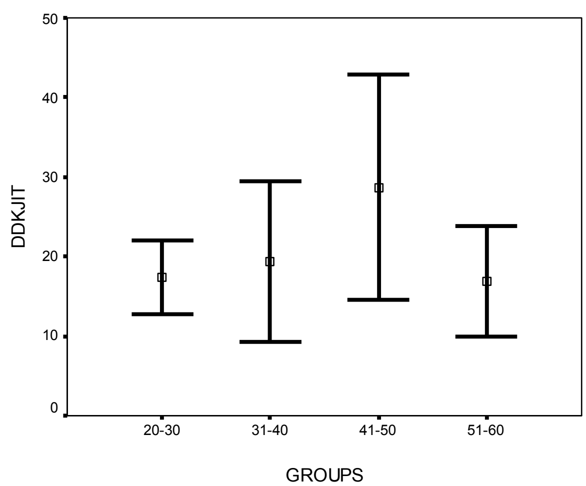


Fig 12: Perturbation of DDK Period of females for age groups between 20-60 years



6. Average DDK Peak Intensity (DDK avi) (dB)

The results for DDK avi are presented in Table 6 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	66.24	66.62	5.79	4.81	54.35	56.79	78.96	76.11	24.61	19.32
30-40	65.46	64.13	6.67	6.07	55.63	55.86	80.03	82.82	24.39	26.97
40-50	64.97	61.87	6.21	6	56.33	55.41	83.87	82.82	27.54	27.41
50-60	65.44	62.60	6.63	5.41	55.96	55.35	80.26	76	24.30	20.65

The mean DDK avi for males in the age group of 20-30 years was found to be 66.24 (SD = 5.79) whereas in females it was 66.62 (SD = 4.81). The range of DDK avi in males was observed as 24.61and in females it was 19.32. The minimum DDK avi in males was 54.35 and in females it was 56.79. The maximum DDK avi in males was 78.96 and 76.11 in females. The mean DDK avi for males in the age group of 30-40 years was found to be 65.46 (SD = 6.67) whereas in females it was 64.13 (SD = 6.07). The range of DDK avi in males was observed as 24.39 and in females it was 26.97. The minimum DDK avi in males was 55.63 and in females it was 55.86. The maximum DDK avi in males was 80.03 and 82.82 in females. The mean DDK avi for males in the age group of 40-50 years was found to be 64.97 (SD = 6.21) whereas in females it was 61.87 (SD = 6). The range of DDK avi in males was observed as 27.54 and in females it was 27.41. The minimum DDK avi in males was 56.33 and in females it was 55.41. The maximum DDK avi in males was 83.87 and 82.82 in females. The mean DDK avi for males in the age group of 50-60 years was found to be 65.44 (SD = 6.63) whereas in females it was 62.60 (SD =

5.41). The range of DDK avi in males was observed as 24.30 and in females it was 20.65. The minimum DDK avi in males was 55.96 and in females it was 55.35. The maximum DDK avi in males was 80.26 and 76 in females. There was significant main effect of age observed in females ($F(3,195) = 6.983$, $p < .000$) while no such significant effect was found in males ($F(3,196) = .341$, $p < .796$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=63.86, SD=5.85) and males (M=65.53, SD=6.3) reveal significant difference t(395)= -2.72, p=.007.

Fig 13: Average DDK Peak Intensity of males for age groups between 20-60 years

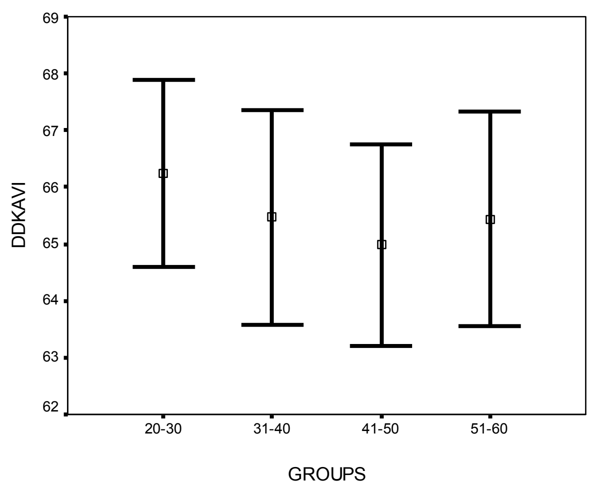
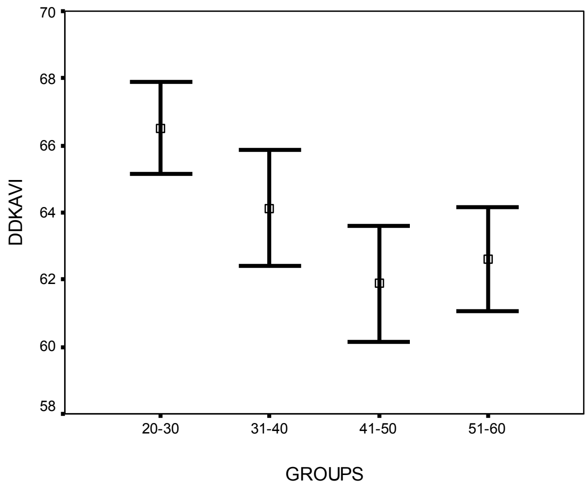


Fig 14: Average DDK Peak Intensity of females for age groups between 20-60 years



7. Standard Deviation of DDK Peak Intensity (DDK sdi) (dB)

The results for DDK sdi are presented in Table 7 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	3.71	3.24	1.90	1.62	.64	.52	7.85	9.18	7.21	8.66
30-40	4.47	3.55	2.42	2.13	.60	.57	8.98	8.56	8.38	7.99
40-50	4.08	3.38	2.48	2.53	.39	.04	9.73	10.81	9.35	10.78
50-60	4.33	4.44	2.39	2.55	.64	.24	9.26	10.81	8.62	10.57

The mean DDK sdi for males in the age group of 20-30 years was found to be 3.71 (SD = 1.90) whereas in females it was 3.24 (SD = 1.62). The range of DDK sdi in males was observed as 7.21 and in females it was 8.66. The minimum DDK sdi in males was .64 and in females it was .52. The maximum DDK sdi in males was 7.85 and 9.18 in females. The mean DDK sdi for males in the age group of 30-40 years was found to be 4.47 (SD = 2.42) whereas in females it was 3.55 (SD = 2.13). The range of DDK sdi in males was observed as 8.38 and in females it was 7.99. The minimum DDK sdi in males was .60 and in females it was .57. The maximum DDK sdi in males was 8.98 and 8.56 in females. The mean DDK sdi for males in the age group of 40-50 years was found to be 4.08 (SD =

2.48) whereas in females it was 3.38 (SD = 2.53). The range of DDK sdi in males was observed as 9.35 and in females it was 10.78. The minimum DDK sdi in males was .39 and in females it was .04. The maximum DDK sdi in males was 9.73 and 10.81 in females. The mean DDK sdi for males in the age group of 50-60 years was found to be 4.33 (SD = 2.39) whereas in females it was 4.44 (SD = 2.55). The range of DDK sdi in males was observed as 8.62 and in females it was 10.57. The minimum DDK sdi in males was .64 and in females it was .24. The maximum DDK sdi in males was 9.26 and 10.81 in females. The One-way ANOVA revealed significant effect of age between the different groups of participants in females ($F(3,191) = 2.807$, $p < .041$) while no significant difference was seen in males ($F(3,192) = 1.014$, $p < .388$). The independent t-test between the females (M=3.65, SD=2.27) and males (M=4.15, SD=2.31) reveal significant difference t(389)= -2.16, p=.03

Fig 15: Standard Deviation of DDK Peak Intensity of males for age groups between 20-60 years

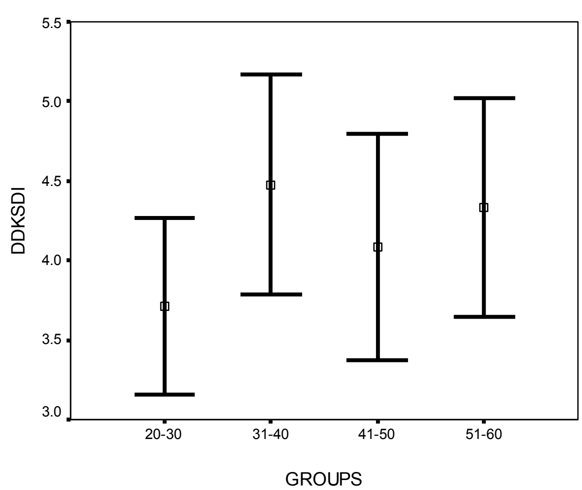
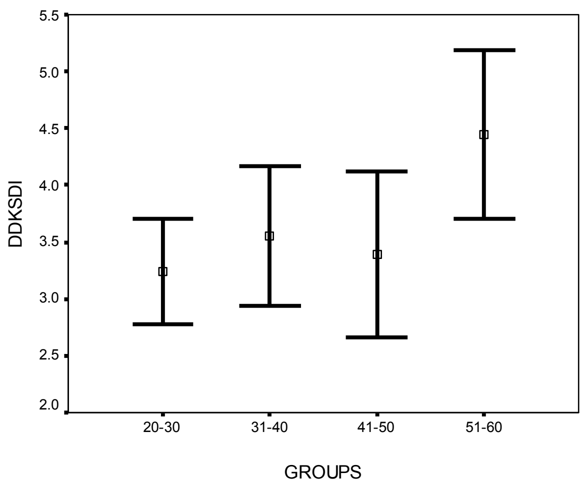


Fig 16: Standard Deviation of DDK Peak Intensity of females for age groups between 20-60 years



8. Coefficient of Variation of DDK Peak Intensity (DDK cvi) (%)

The results for DDK cvi are presented in Table 8 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	5.52	4.83	2.60	2.25	1.14	.68	10.38	12.72	9.24	12.04
30-40	6.64	5.45	3.31	3.16	1.08	1.02	12.64	13.26	11.56	12.23
40-50	6.12	5.23	3.44	3.58	.64	.06	13.79	14.89	13.16	14.83
50-60	6.44	6.86	3.14	3.58	1.14	.43	12.24	14.89	11.10	14.46

The mean DDK cvi for males in the age group of 20-30 years was found to be 5.52 (SD = 2.60) whereas in females it was 4.83 (SD = 2.25). The range of DDK cvi in males was observed as 9.24 and in females it was 12.04. The minimum DDK cvi in males was 1.14 and in females it was .68. The maximum DDK cvi in males was 10.38 and 12.72 in females. The mean DDK cvi for males in the age group of 30-40 years was found to be 6.64 (SD = 3.31) whereas in females it was 5.45 (SD = 3.16). The range of DDK cvi in males was observed as 11.56 and in females it was 12.23. The minimum DDK cvi in males was 1.08 and in females it was 1.02. The maximum DDK cvi in males was 12.64

and 13.26 in females. The mean DDK cvi for males in the age group of 40-50 years was found to be 6.12 (SD = 3.44) whereas in females it was 5.23 (SD = 3.58). The range of DDK cvi in males was observed as 13.16 and in females it was 14.83. The minimum DDK cvi in males was .64 and in females it was .06. The maximum DDK cvi in males was 13.79 and 14.89 in females.

The mean DDK cvi for males in the age group of 50-60 years was found to be 6.44 (SD = 3.14) whereas in females it was 6.86 (SD = 3.58). The range of DDK cvi in males was observed as 11.10 and in females it was 14.46. The minimum DDK cvi in males was 1.14 and in females it was .43. The maximum DDK cvi in males was 12.24 and 14.89 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,191) = 3.704$, $p < .013$) while no significant difference was observed in males ($F(3,188) = 1.164$, $p < .325$). The independent t-test between the females (M=5.59, SD=3.25) and males (M=6.18, SD=3.15) did not reveal significant difference $t(389) = -1.82$, $p = .06$

Fig 17: Coefficient Variation of DDK Peak Intensity of males for age groups between 20-60 years

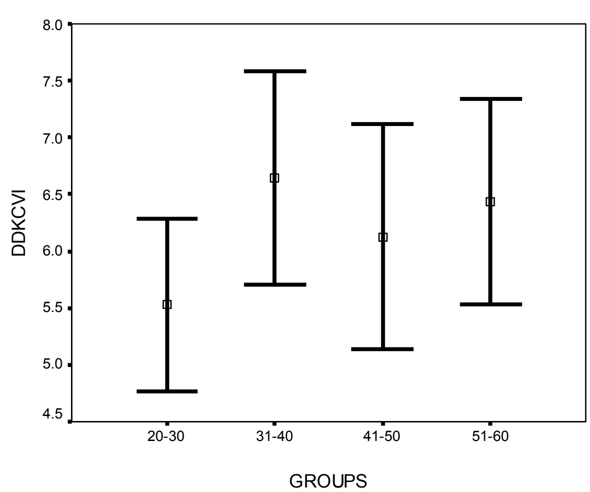
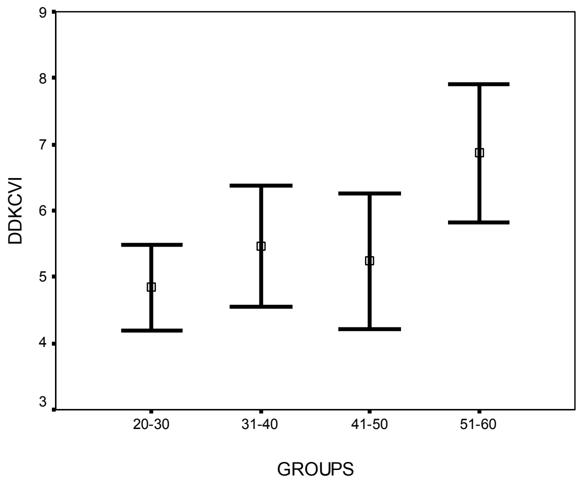


Fig 18: Coefficient Variation of DDK Peak Intensity of females for age groups between 20-60 years



9. Maximum Intensity of DDK Sample (DDK mxa) (dB)

The results for DDK mxa are presented in Table 9 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	72.77	72.22	7.47	5.78	54.97	57.31	88.93	87.46	33.96	30.15
30-40	74.91	71.55	9.32	8.85	57.35	56.63	90.31	90.31	32.96	33.68
40-50	73.58	68.82	8.99	10.22	54.30	50.43	89.81	88.60	35.52	38.17
50-60	74.31	72.38	8.60	9.85	57.34	55.35	87.98	89.75	30.64	34.40

The mean DDK mxa for males in the age group of 20-30 years was found to be 72.77 (SD = 7.47) whereas in females it was 72.22 (SD = 5.78). The range of DDK mxa in males was observed as 33.96 and in females it was 30.15. The minimum DDK mxa in males was 54.97 and in females it was 57.31. The maximum DDK mxa in males was 88.93 and 87.46 in females. The mean DDK mxa for males in the age group of 30-40 years was found to be 74.91 (SD = 9.32) whereas in females it was 71.55 (SD = 8.85). The range of DDK mxa in males was observed as 32.96 and in females it was 33.68. The minimum DDK mxa in males was 57.35 and in females it was 56.63. The maximum DDK mxa in males was 90.31and 90.31 in females. The mean DDK mxa for males in the age group of 40-50 years was found to be 73.58 (SD = 8.99) whereas in females it was 68.82 (SD = 10.22). The range of DDK mxa in males was observed as 35.52 and in females it was 38.17. The minimum DDK mxa in males was 54.30 and in females it was 50.43. The maximum DDK mxa in males was 89.81 and 88.60 in females. The mean DDK mxa for males in the age group of 50-60 years was found to be 74.31 (SD = 8.60) whereas in females it was 72.38 (SD = 9.85). The range of DDK mxa in males was observed as 30.64 and in females it was 34.40. The minimum DDK mxa in males was 57.34 and in females it was 55.35. The maximum DDK mxa in males was 87.98 and 89.75 in females. No significant main effect of age was observed in either females ($F(3,196) = 1.751$, $p < .158$) or males ($F(3,196) = .575$, $p < .632$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=71.24, SD=8.9) and males (M=73.9, SD=8.6) reveal significant difference $t(389) = -3.02$, $p = .003$

Fig 19: Maximum Intensity of DDK Sample of males for age groups between 20-60 years

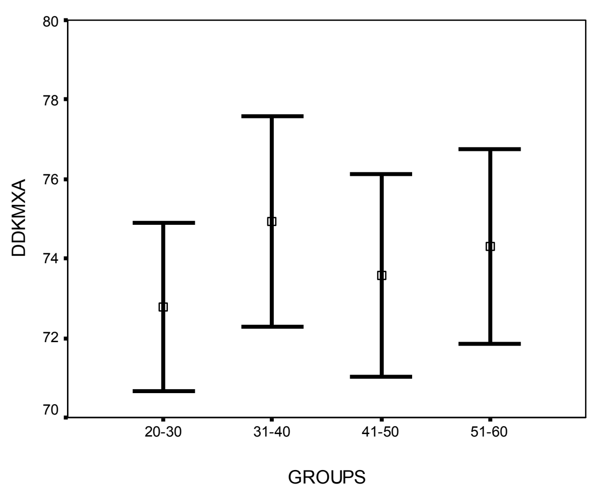
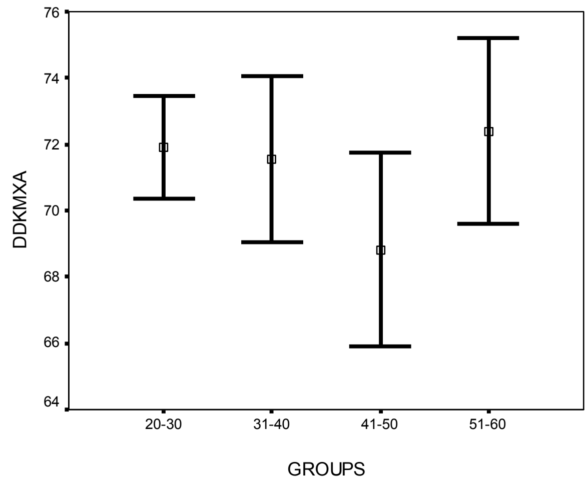


Fig 20: Maximum Intensity of DDK Sample of females for age groups between 20-60 years



10. Average Intensity of DDK Sample (DDK ava) (dB)

The results for DDK ava are presented in Table 10 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	59.02	61.58	7.67	5.71	44.23	44.92	69.57	67.48	25.34	22.56
30-40	54.51	54.64	6.71	7.57	44.75	42.79	67.06	66.52	22.31	23.72
40-50	53.36	50.74	5.83	6.44	44.58	42.85	66.82	65.38	22.24	22.52
50-60	54.54	51.84	6.21	6.79	45.36	42.16	67.97	65.28	22.61	23.12

The mean DDK ava for males in the age group of 20-30 years was found to be 59.02 (SD = 7.67) whereas in females it was 61.58 (SD = 5.71). The range of DDK ava in males was observed as 25.34 and in females it was 22.56. The minimum DDK ava in males was 44.23 and in females it was 44.92. The maximum DDK ava in males was 69.57 and 67.48 in females. The mean DDK ava for males in the age group of 30-40 years was found to be 54.51 (SD = 6.71) whereas in females it was 54.64 (SD = 7.57). The range of DDK ava in males was observed as 22.31 and in females it was 23.72. The minimum DDK ava in males was 44.75 and in females it was 42.79. The maximum DDK ava in males was

67.06 and 66.52 in females. The mean DDK ava for males in the age group of 40-50 years was found to be 53.36 (SD = 5.83) whereas in females it was 50.74 (SD = 6.44). The range of DDK ava in males was observed as 22.24 and in females it was 22.52. The minimum DDK ava in males was 44.58 and in females it was 42.85. The maximum DDK ava in males was 66.82 and 65.38 in females. The mean DDK ava for males in the age group of 50-60 years was found to be 54.54 (SD = 6.21) whereas in females it was 51.84 (SD = 6.79). The range of DDK ava in males was observed as 22.61 and in females it was 23.12. The minimum DDK ava in males was 45.36 and in females it was 42.16. The maximum DDK ava in males was 67.97 and 65.28 in females. There was significant age effect in both males [F(3,196)=7.09, p=0.000] and females [F(3,196)=26.71, p=0.000] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=54.7, SD=7.8) and males (M=55.36, SD=6.94) did not reveal significant difference t(389)= -0.9, *p*=.37

Fig 21: Average Intensity of DDK Sample of males for age groups between 20-60 years

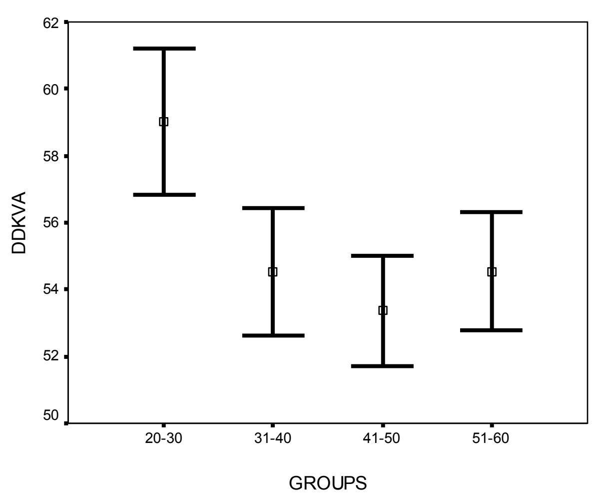
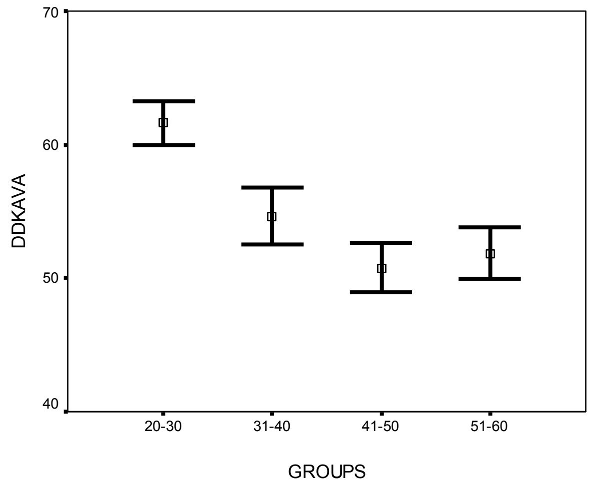


Fig 22: Average Intensity of DDK Sample of females for age groups between 20-60 years



11. Average Syllabic Intensity (DDK sla) (dB)

The results for DDK sla are presented in Table 11 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	63.43	64.71	3.77	3.95	54.16	56.57	69.70	75.95	15.54	19.38
30-40	62.36	62.12	4.15	3.88	55.57	55.70	71.06	70.26	15.49	14.56
40-50	61.82	60.23	3.62	4.19	56.17	55.31	70.85	70.22	14.68	14.90
50-60	61.99	60.63	3.69	3.61	55.68	55.35	68.49	67.53	12.80	12.18

The mean DDK sla for males in the age group of 20-30 years was found to be 63.43 (SD = 3.77) whereas in females it was 64.71 (SD = 3.95). The range of DDK sla in males was observed as 15.54 and in females it was 19.38. The minimum DDK sla in males was 54.16 and in females it was 56.57. The maximum DDK sla in males was 69.70 and 75.95 in females. The mean DDK sla for males in the age group of 30-40 years was found to be 62.36 (SD = 4.15) whereas in females it was 62.12 (SD = 3.88). The range of DDK sla in males was observed as 15.49 and in females it was 14.56. The minimum DDK sla in males was 55.57 and in females it was 55.70. The maximum DDK sla in males was 71.06 and 70.26 in females. The mean DDK sla for males in the age group of 40-50 years was found to be 61.82 (SD = 3.62) whereas in females it was 60.23 (SD = 4.19). The range of

DDK sla in males was observed as 14.68 and in females it was 14.90. The minimum DDK sla in males was 56.17 and in females it was 55.31. The maximum DDK sla in males was 70.85 and 70.22 in females. The mean DDK sla for males in the age group of 50-60 years was found to be 61.99 (SD = 3.69) whereas in females it was 60.63 (SD = 3.61). The range of DDK sla in males was observed as 12.80 and in females it was 12.18. The minimum DDK sla in males was 55.68 and in females it was 55.35. The maximum DDK sla in males was 68.49 and 67.53 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,195) = 13.365$, $p < .000$) while no significant difference was observed in males ($F(3,195) = 1.792$, $p < .150$). The independent t-test between the females (M=61.93, SD=4.3) and males (M=62.4, SD=3.84) did not reveal significant difference t(386)= -1.15, p=.24

Fig 23: Average Syllabic Intensity of males for age groups between 20-60 years

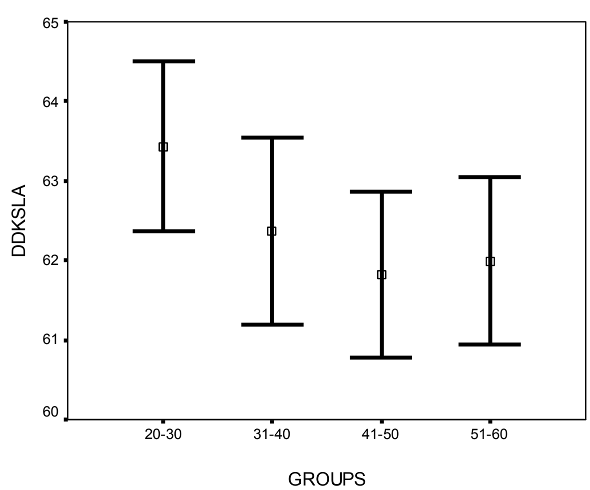
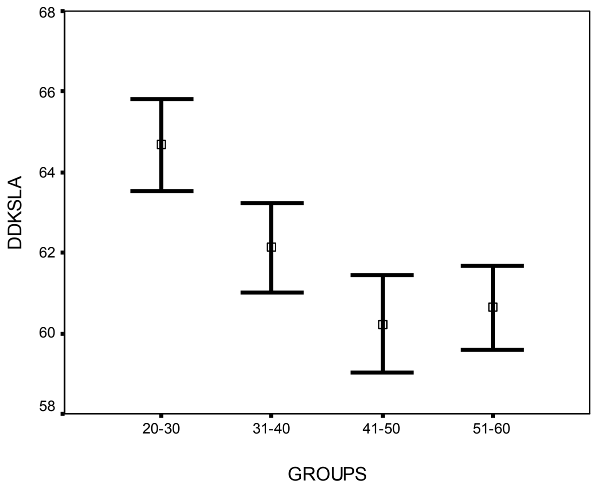


Fig 24: Average Syllabic Intensity of females for age groups between 20-60 years



Second Formant Transition

1. Magnitude of F2 variation (F2magn) (Hz)

The results for F2magn are presented in Table 12 below.

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	133.99	122.84	32.46	64.58	69.96	68.48	258.23	356.45	188.27	287.97
30-40	490.38	638.88	191.82	170.19	103.11	102.45	769.05	876.32	665.94	773.87
40-50	543.94	678.55	157.79	236.48	127.63	75.97	739.33	910.55	611.70	834.58
50-60	523.64	691.05	189.92	148.45	75.02	216.70	773.43	918.36	698.41	701.66

The mean F2magn for males in the age group of 20-30 years was found to be 133.99 (SD = 32.46) whereas in females it was 122.84 (SD = 64.58). The range of F2magn in males was observed as 188.27 and in females it was 287.97. The minimum F2magn in males was 69.96 and in females it was 68.48. The maximum F2magn in males was 258.23 and 356.45 in females. The mean F2magn for males in the age group of 30-40 years was found to be 490.38 (SD = 191.82) whereas in females it was 638.88 (SD = 170.19). The range of F2magn in males was observed as 665.94 and in females it was 773.87. The minimum F2magn in males was 103.11 and in females it was 102.45. The maximum F2magn in males was 769.05 and 876.32 in females. The mean F2magn for males in the age group of 40-50 years was found to be 543.94 (SD = 157.79) whereas in females it was 678.55 (SD = 236.48). The range of F2magn in males was observed as 611.70 and in females it was 834.58. The minimum F2magn in males was 127.63 and in females it was 75.97. The maximum F2magn in males was 739.33 and 910.55 in females. The mean F2magn for males in the age group of 50-60 years was found to be 523.64 (SD = 189.92) whereas in females it was 691.05 (SD = 148.45). The range of F2magn in males was observed as 698.41 and in females it was 701.66. The minimum F2magn in males was 75.02 and in females it was 216.70. The maximum F2magn in males was 773.43 and 918.36 in females. There was a significant age effect in both males [F(3,189)=74.4, p=.00] and females [F(3,170)=133.291, p=.00] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=477.45, SD=318.48) and males (M=467.78, SD=219.68) did not reveal significant difference t(359)=.34, *p*=.73

Fig 25: Magnitude of F2 variation of males for age groups between 20-60 years

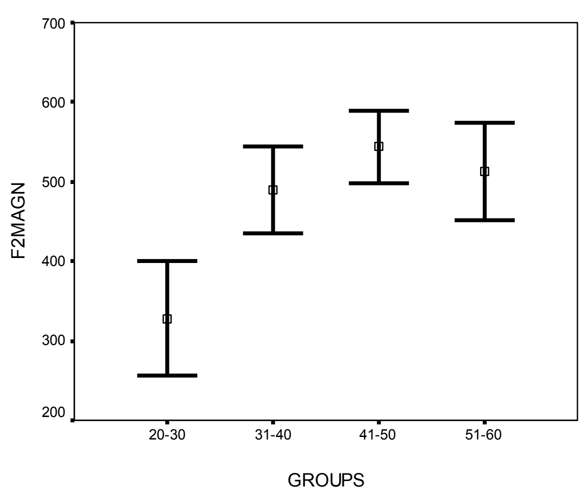
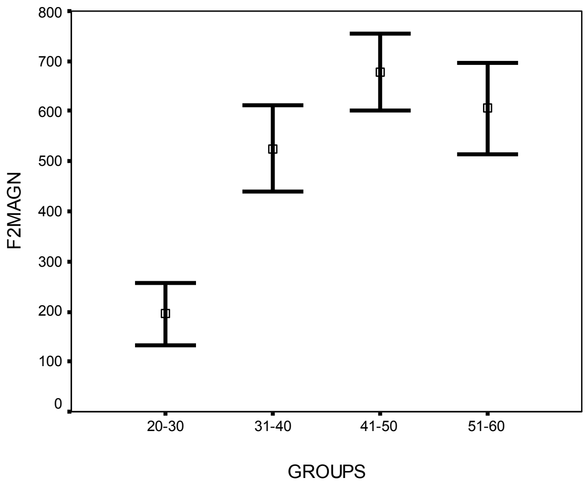


Fig 26: Magnitude of F2 variation of females for age groups between 20-60 years



2. Rate of F2 Variation (F2rate) (/s)

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	2.04	2.31	1.09	.85	.73	1.19	3.28	3.77	2.55	2.58
30-40	1.83	1.74	.63	1.06	1.14	1.12	3.45	3.64	2.31	2.52
40-50	1.16	2.00	.18	1.66	.96	.83	1.32	3.18	.36	2.35
50-60	1.56	4.03	.27	2.51	1.11	2.17	1.92	6.90	.81	4.72

The mean F2rate for males in the age group of 20-30 years was found to be 2.04 (SD = 1.09) whereas in females it was 2.31 (SD = .85). The range of F2rate in males was observed as 2.55 and in females it was 2.58. The minimum F2rate in males was .73 and in females it was 1.19. The maximum F2rate in males was 3.28 and 3.77 in females. The mean F2rate for males in the age group of 30-40 years was found to be 1.83 (SD = .63) whereas in females it was 1.74 (SD = 1.06). The range of F2rate in males was observed as 2.31 and in females it was 2.52. The minimum F2rate in males was 1.14and in females it was 1.12. The maximum F2rate in males was 3.45 and 3.64 in females. The mean F2rate for males in the age group of 40-50 years was found to be 1.16 (SD = .18) whereas in females it was 2 (SD = 1.66). The range of F2rate in males was observed as .36 and in females it was 2.35. The minimum F2rate in males was .96 and in females it was .83. The maximum F2rate in males was 1.32 and 3.18 in females. The mean F2rate for males in the age group of 50-60 years was found to be 1.56 (SD = .27) whereas in females it was 4.03 (SD = .27). The range of F2rate in males was observed as .81 and in females it was 4.72. The minimum F2rate in males was 1.11 and in females it was 2.17. The maximum F2rate in males was 1.92 and 6.90 in females. No significant main effect of age was observed in either females ($F(3,20) = 2.4$, $p < .09$) or males ($F(3,24) = 1.3$, $p < .3$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=2.4, SD=1.31) and males (M=1.74, SD=.7) reveal significant difference $t(50)=2.21$, $p=.03$

Fig 27: Rate of F2 Variation of males for age groups between 20-60 years

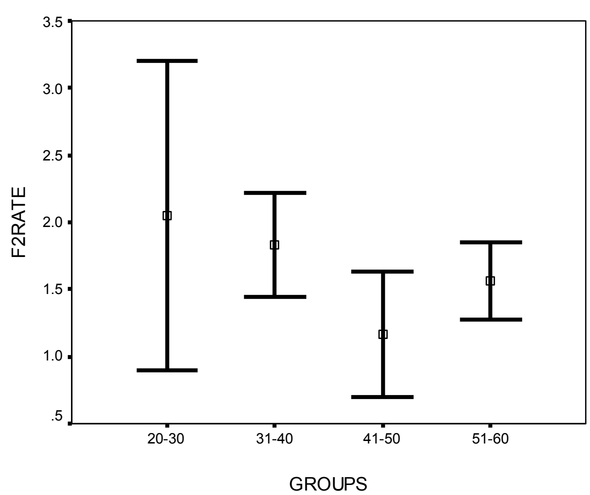
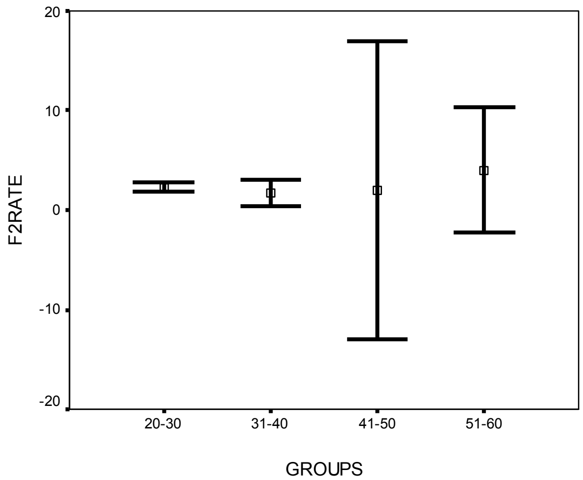


Fig 28: Rate of F2 Variation of females for age groups between 20-60 years



3. Regularity of F2 Variation (F2reg) (%)

The results for F2reg are presented in Table 14 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	60.34	55.54	20.65	14.55	41.63	40.40	95.59	89.81	53.97	49.40
30-40	71.49	74.29	26.10	25.53	41.67	43.70	96.79	95.79	55.12	52.09
40-50	77.30	78.05	31.49	6.77	40.93	73.26	95.59	82.85	54.66	9.59
50-60	91.86	53.04	4.40	9.59	85.09	42.19	97.03	60.38	11.94	18.19

The mean F2reg for males in the age group of 20-30 years was found to be 60.34 (SD = 20.65) whereas in females it was 55.54 (SD = 14.55). The range of F2reg in males was observed as 53.97 and in females it was 49.40. The minimum F2reg in males was 41.63 and in females it was 40.40. The maximum F2reg in males was 95.59 and 89.81 in females. The mean F2reg for males in the age group of 30-40 years was found to be 71.49 (SD = 26.10) whereas in females it was 74.29 (SD = 25.53). The range of F2reg in males was observed as 55.12 and in females it was 52.09. The minimum F2reg in males was 41.67 and in females it was 43.70. The maximum F2reg in males was 96.79 and 95.79 in females. The mean F2reg for males in the age group of 40-50 years was found to be 95.79 (SD = 31.49) whereas in females it was 78.05 (SD = 6.77). The range of F2reg in males was observed as 54.66 and in females it was 9.59. The minimum F2reg in males was 40.93 and in females it was 73.26. The maximum F2reg in males was 95.59 and 82.85 in females. The mean F2reg for males in the age group of 50-60 years was found to be 91.86 (SD = 4.40) whereas in females it was 53.04 (SD = 9.59). The range of F2reg in males was observed as 11.94 and in females it was 18.19. The minimum F2reg in males was 85.09 and in females it was 42.19. The maximum F2reg in males was 97.03 and 60.38 in females. No significant main effect of age was observed in either females ($F(3,20) = 2.5$, $p < .09$) or males ($F(3,24) = 2.03$, $p < .14$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=61.01, SD=18.25) and males (M=74.09, SD=23.99) revealed significant difference t(50)= -2.18, p=.03.

Fig 29: Regularity of F2 Variation of males for age groups between 20-60 years

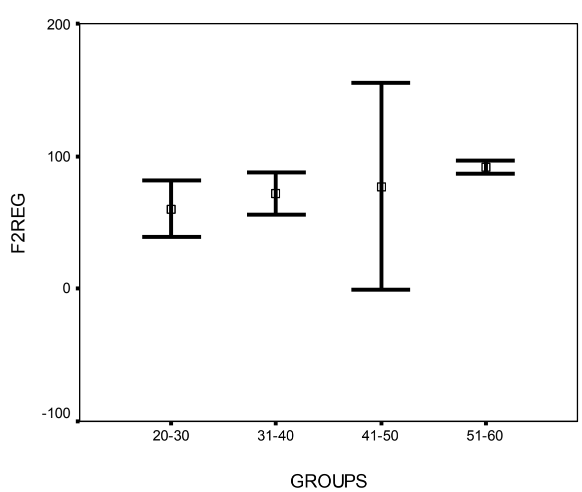
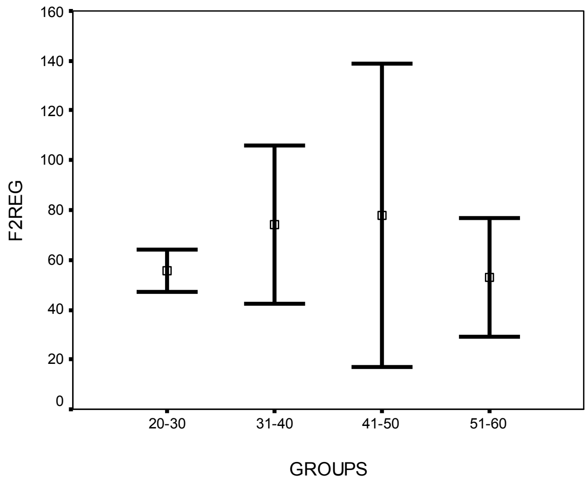


Fig 30: Regularity of F2 Variation of females for age groups between 20-60 years



4. Average of F2 Value (F2aver) (Hz)

The results for F2 aver are presented in Table 15 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	1727.44	1396.74	93.17	345.86	1438.66	782.94	1918.84	2312.56	480.18	1529.63
30-40	1653.95	1774.96	121.18	353.01	1361.98	1210.90	1978.20	2341.27	616.22	1130.37
40-50	1649.98	1920.71	143.56	292.03	1428.53	1235.40	1912.43	2310.25	483.91	1074.84
50-60	1565.02	1792.34	180.70	313.46	1233.62	1191.96	1978.20	2181.76	744.58	989.81

The mean F2aver for males in the age group of 20-30 years was found to be 1727.44 (SD = 93.17) whereas in females it was 1396.74 (SD = 345.86). The range of F2aver in males was observed as 480.18 and in females it was 1529.63. The minimum F2aver in males was 1438.66 and in females it was 782.94. The maximum F2aver in males was 1918.84 and 2312.56 in females. The mean F2aver for males in the age group of 30-40 years was found to be 1653.95 (SD = 121.18) whereas in females it was 1774.96 (SD = 353.01). The range of F2aver in males was observed as 616.22 and in females it was 1130.37. The minimum F2aver in males was 1361.98 and in females it was 1210.90. The maximum F2aver in males was 1978.20 and 2341.27 in females. The mean F2aver for males in the age group of 40-50 years was found to be 1649.98 (SD = 143.56) whereas in females it was 1920.71 (SD = 292.03). The range of F2aver in males was observed as 483.91and in females it was 1074.84. The minimum F2aver in males was 1428.53 and in females it was 1235.40. The maximum F2aver in males was 1912.43 and 2310.25 in females. The mean F2aver for males in the age group of 50-60 years was found to be 1565.02 (SD = 180.70) whereas in females it was 1792.34 (SD = 313.46). The range of F2aver in males was observed as 744.58 and in females it was 989.81. The minimum F2aver in males was 1233.62 and in females it was 1191.96. The maximum F2aver in males was 1978.20 and 2181.76 in females. There was a significant age effect in both females [F(3,170)=21.617, p=.00] and males [F(3,189)=11.048, p=.00] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=1702.44, SD=384.87) and males (M=1650.42, SD=147.92) did not reveal significant difference t(365)=1.74, *p*=.08

Fig 31: Average of F2 Value of males for age groups between 20-60 years

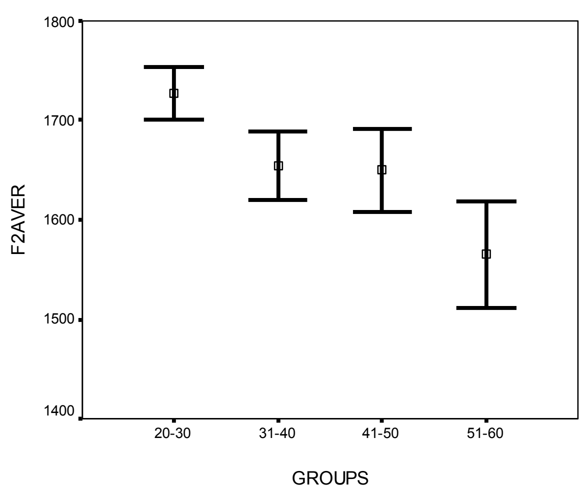
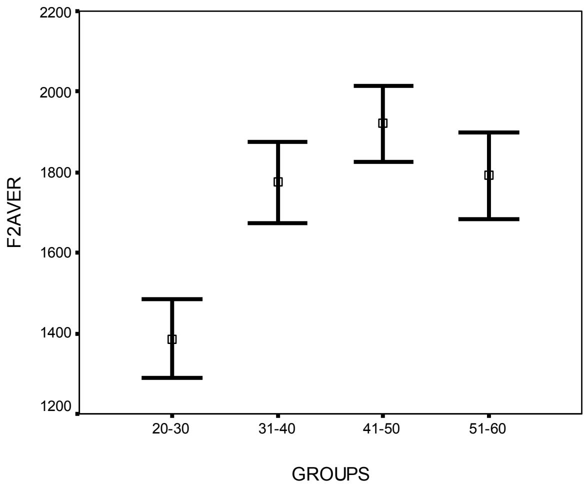


Fig 32: Average of F2 Value of females for age groups between 20-60 years



5. Minimum F2 Value (F2min) (Hz)

The results for F2min are presented in Table 16 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	991.57	601.64	313.73	174.52	354	288	1340	908	986	620
30-40	701.06	624.88	288.79	214.72	315	295	1314	1438	999	1143
40-50	589.58	556.76	244.37	149.20	339	382	1324	908	985	526
50-60	544.76	553.65	200.11	144.20	104.88	357	993	908	888.12	551

The mean F2min for males in the age group of 20-30 years was found to be 991.57 (SD = 313.73) whereas in females it was 601.64 (SD = 174.52). The range of F2min in males was observed as 986 and in females it was 620. The minimum F2min in males was 354 and in females it was 288. The maximum F2min in males was 1340 and 908 in females. The mean F2min for males in the age group of 30-40 years was found to be 701.06 (SD = 288.79) whereas in females it was 624.88 (SD = 214.72). The range of F2min in males was observed as 999 and in females it was 1143. The minimum F2min in males was 315 and in females it was 295. The maximum F2min in males was 1314 and 1438 in females. The mean F2min for males in the age group of 40-50 years was found to be 589.58 (SD = 244.37) whereas in females it was 556.76 (SD = 149.20). The range of F2min in males was observed as 985 and in females it was 526. The minimum F2min in males was 339 and in females it was 382. The maximum F2min in males was 1324 and 908 in females. The mean F2min for males in the age group of 50-60 years was found to be 544.76 (SD = 200.11) whereas in females it was 553.65 (SD = 144.20). The range of F2min in males was observed as 888.12 and in females it was 551. The minimum F2min in males was 104.88 and in females it was 357. The maximum F2min in males was 993 and 908 in females. No significant main effect of age was observed in females ($F(3,170) = 1.67$, $p <$ .175) and significant difference was observed in males ($F(3,190) = 27.61$, $p < .00$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=603.55, SD=202.1) and males (M=703.32, SD=318.96) reveal significant difference t(366)=-3.54, p=.00

Fig 33: Minimum F2 Value of males for age groups between 20-60 years

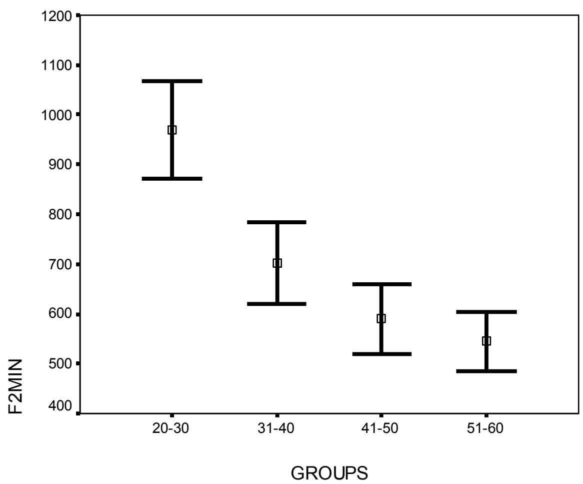
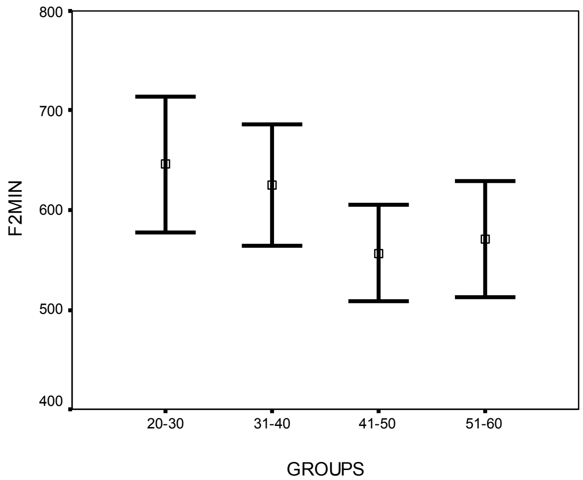


Fig 34: Minimum F2 Value of females for age groups between 20-60 years



6. Maximum F2 Value (F2max) (Hz)

The results for F2 max are presented in Table 17 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	2387.38	1944.22	220.72	521.25	1898	1593	2811	3290	913	1697
30-40	2466.54	2633.06	214.11	643.45	1828	1566	2957	3410	1129	1844
40-50	2535.06	2895.82	170.94	458.57	2198	1640	2847	3279	649	1639
50-60	2441.21	2772.60	358.98	555.36	1560	1607	2847	3303	1287	1696

The mean F2max for males in the age group of 20-30 years was found to be 2387.38 (SD = 220.72) whereas in females it was 1944.22 (SD = 521.25). The range of F2max in males was observed as 913 and in females it was1697. The minimum F2max in males was 1898 and in females it was 1593. The maximum F2max in males was 2811 and 3290 in females. The mean F2max for males in the age group of 30-40 years was found to be 2466.54 (SD = 214.11) whereas in females it was 2633.06 (SD = 643.45). The range of F2max in males was observed as 1129 and in females it was 1844. The minimum F2max in males was 1828 and in females it was 1828. The maximum F2max in males was 2957 and 3410 in females. The mean F2max for males in the age group of 40-50 years was found to be 2535.06 (SD = 170.94) whereas in females it was 2895.82 (SD = 458.57). The range of F2max in males was observed as 649 and in females it was 1639. The minimum F2max in males was 2198 and in females it was 1640. The maximum F2max in males was 2847 and 2847 in females. The mean F2max for males in the age group of 50-

60 years was found to be 2441.21 (SD = 358.98) whereas in females it was 2772.60 (SD = 555.36). The range of F2max in males was observed as 1287 and in females it was 1696. The minimum F2max in males was 1560 and in females it was 1607. The maximum F2max in males was 2847 and 3303 in females. There was a significant age effect in both females [F(3,170)=27.15, p=.00] and males [F(3,189)=2.925, p=.03] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=2522.1, SD=667.3) and males (M=2457.45, SD=253.14) did not reveal significant difference t(365)=1.25, *p*=.2

Fig 35: Maximum F2 Value of males for age groups between 20-60 years

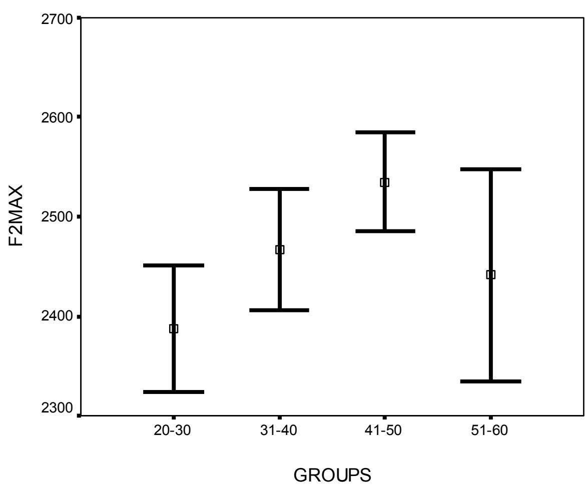
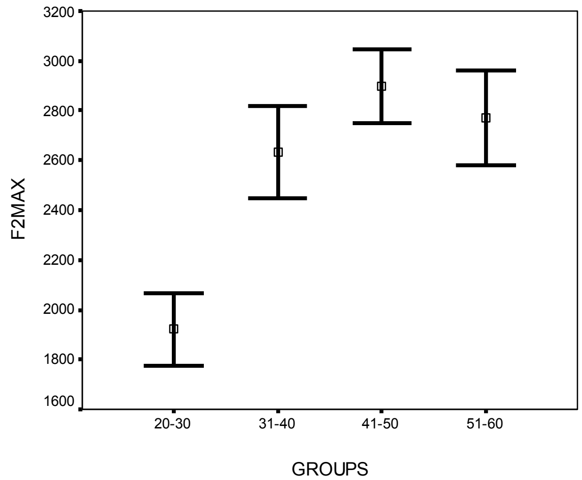


Fig 36: Maximum F2 Value of females for age groups between 20-60 years



Voice Parameters

1. Average Fundamental Frequency (F0) (Hz)

The results for F0 are presented in Table 18 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	124.98	213.22	14.98	25.54	98.97	158.49	165.40	262.47	66.43	103.98
30-40	126.02	202.15	22.36	21.73	91.41	141.92	238.77	248.07	147.37	106.15
40-50	121.12	198.79	15	24.64	86.38	143.87	157.05	253.96	70.67	110.10
50-60	124.27	191.85	18.73	30.58	90.89	108.84	157.94	263.25	67.05	154.42

The mean F0 for males in the age group of 20-30 years was found to be 124.98 (SD = 14.98) whereas in females it was 213.22 (SD = 25.54). The range of F0 in males was observed as 66.43 and in females it was 103.98. The minimum F0 in males was 98.97 and in females it was 158.49. The maximum F0 in males was 165.40 and 262.47 in females. The mean F0 for males in the age group of 30-40 years was found to be 126.02 (SD = 22.36) whereas in females it was 202.15 (SD = 21.73). The range of F0 in males was observed as 147.37 and in females it was 106.15. The minimum F0 in males was 91.41 and in females it was 141.92. The maximum F0 in males was 238.77 and 248.07 in females. The mean F0 for males in the age group of 40-50 years was found to be 121.12 (SD = 15) whereas in females it was 198.79 (SD = 24.64). The range of F0 in males was observed as 70.67 and in females it was 110.10. The minimum F0 in males was 86.38 and in females it was 143.87. The maximum F0 in males was 157.05 and 253.96 in females.

The mean F0 for males in the age group of 50-60 years was found to be 124.27 (SD = 18.73) whereas in females it was 191.85 (SD = 30.58). The range of F0 in males was observed as 67.05 and in females it was 154.42. The minimum F0 in males was 90.89 and in females it was 108.84. The maximum F0 in males was 157.94 and 263.25 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,193) = 5.85$, $p < .001$) while no significant difference was observed in males ($F(3,196) = 0.68$, $p < .6$). The independent t-test between the females (M=201.65, SD=26.68) and males (M=132.1, SD=113.63) reveal significant difference t(395)=8.36, p=.00

Fig 37: Average Fundamental Frequency of females for age groups between 20-60 years

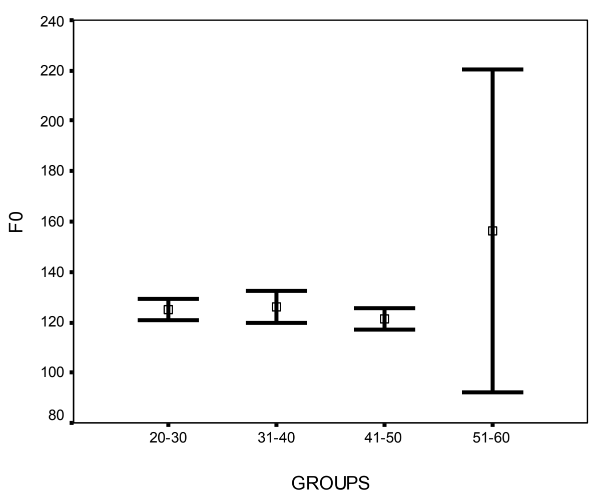
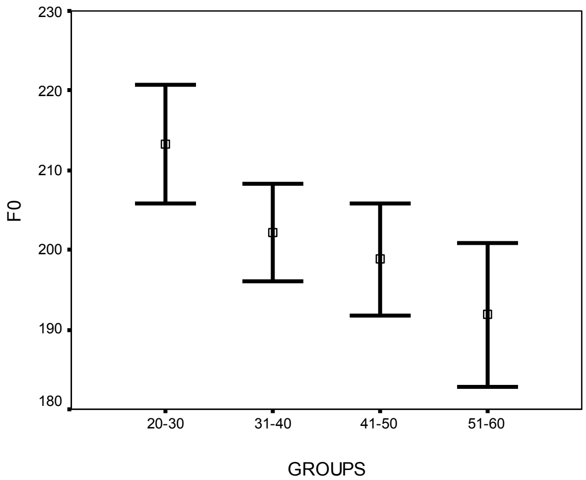


Fig 38: Average Fundamental Frequency of females for age groups between 20-60 years



2. Average Pitch Period (To) (ms)

The results for T_o are presented in Table 19 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	8.11	4.76	.93	.62	6.05	3.81	10.10	6.31	4.06	2.50
30-40	8.12	5.00	1.14	.59	4.19	4.03	10.94	7.05	6.75	3.02
40-50	8.39	5.11	1.11	.67	6.37	3.94	11.58	6.95	5.21	3.01
50-60	8.19	5.34	1.29	.92	6.33	3.80	11	9.19	4.67	5.39

The mean T_o for males in the age group of 20-30 years was found to be 8.11 (SD = .93) whereas in females it was 4.76 (SD = .62). The range of T_o in males was observed as 4.06 and in females it was 2.50. The minimum T_o in males was 6.05 and in females it was 3.81. The maximum T_o in males was 10.10 and 6.31 in females. The mean T_o for males in the age group of 30-40 years was found to be 8.12 (SD = 1.14) whereas in females it was 5 (SD = .59). The range of T_o in males was observed as 6.75 and in females it was 3.02. The minimum T_o in males was 4.19 and in females it was 4.03. The maximum T_o in males was 10.94 and 7.05 in females. The mean T_o for males in the age group of 40-50 years was found to be 8.39 (SD = 1.11) whereas in females it was 5.11 (SD = .67). The range of T_o in males was observed as 5.21 and in females it was 3.01. The minimum T_o in males was 6.37and in females it was 3.94. The maximum T_o in males was 11.58 and 6.95 in females. The mean T_o for males in the age group of 50-60 years was found to be 8.19 (SD = 1.29) whereas in females it was 5.34 (SD = .92). The range of T_o in males was observed as 4.67 and in females it was 5.39. The minimum T_o in males was 6.33 and in females it was 3.80. The maximum T_o in males was 11 and 9.19 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,193) = 5.62$, $p < .001$) while no significant difference was observed in males ($F(3,196) = 0.65$, $p < .57$). The independent t-test between the females (M=5.05, SD=0.74) and males (M=14.5, SD=89.01) did not reveal significant difference t(395)= -1.49, p=.13

Fig 39: Average Pitch Period of males for age groups between 20-60 years

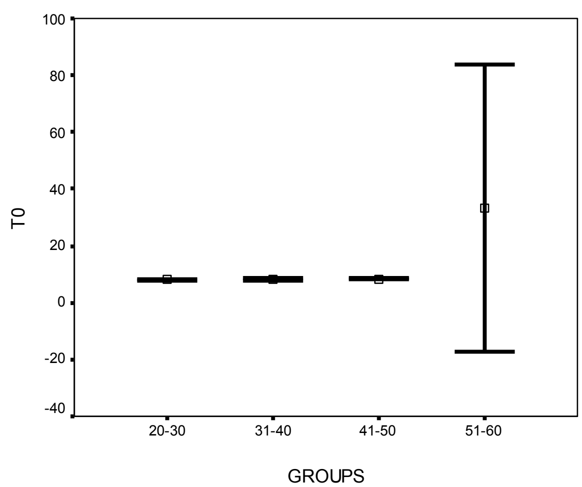
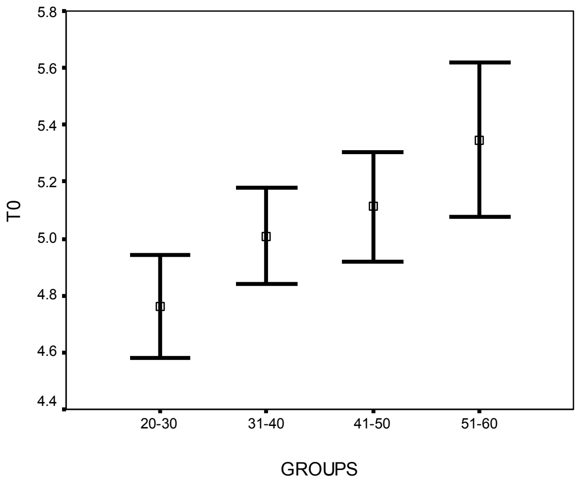


Fig 40: Average Pitch Period of females for age groups between 20-60 years



3. Highest Fundamental Frequency (Fhi) (Hz)

The results for Fhi are presented in Table 20 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	203.78	241.26	160.57	63.19	102.80	164.88	629.41	618.84	526.61	453.96
30-40	163.79	249.83	85.54	82.97	98.32	149.84	629.47	506.49	531.16	356.66
40-50	192.56	313.12	111.55	135.66	87.86	173.52	522.02	624.72	434.16	451.20
50-60	159.03	271.54	79.58	111.62	98.48	164.13	570.24	605.37	471.75	441.24

The mean Fhi for males in the age group of 20-30 years was found to be 203.78 (SD = 160.57) whereas in females it was 241.26 (SD = 63.19). The range of Fhi in males was observed as 526.61 and in females it was 453.96. The minimum Fhi in males was 102.80 and in females it was 164.88. The maximum Fhi in males was 629.41 and 618.84 in females. The mean Fhi for males in the age group of 30-40 years was found to be 163.79 (SD = 85.54) whereas in females it was 249.83 (SD = 82.97). The range of Fhi in males was observed as 531.16 and in females it was 356.66. The minimum Fhi in males was 98.32 and in females it was 149.84. The maximum Fhi in males was 629.47 and 506.49 in females. The mean Fhi for males in the age group of 40-50 years was found to be 192.56 (SD = 111.55) whereas in females it was 313.12 (SD = 135.66). The range of Fhi in males was observed as 434.16 and in females it was 451.20. The minimum Fhi in males was 87.86 and in females it was 173.52. The maximum Fhi in males was 522.02 and 624.72 in females. The mean Fhi for males in the age group of 50-60 years was found to be 159.03 (SD = 79.58) whereas in females it was 271.54 (SD = 111.62). The range of Fhi in males was observed as 471.75 and in females it was 441.24. The minimum Fhi in males was 98.48 and in females it was 164.13. The maximum Fhi in males was 570.24 and 605.37 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,193) = 4.94$, $p < .002$) while no significant difference was observed in males ($F(3,196) = 1.83$, $p < .14$). The independent t-test between the females (M=268.89, SD=105.03) and males (M=193.3, SD=188.1) reveal significant difference t(395)=4.93, p=.00

Fig 41: Highest Fundamental Frequency of males for age groups between 20-60 years

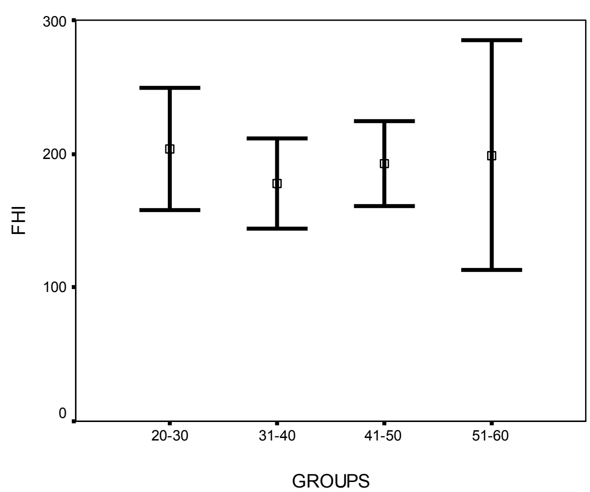
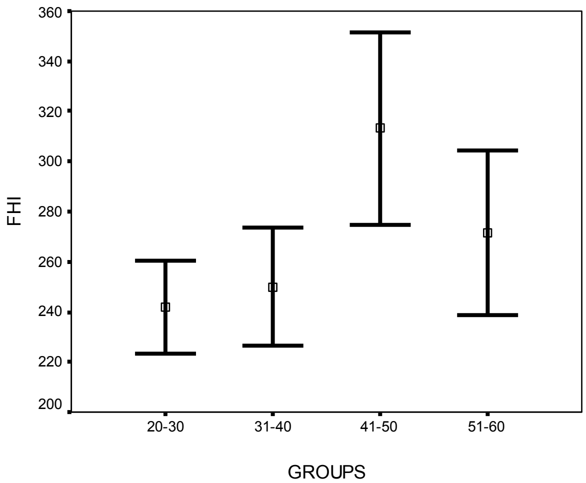


Fig 42: Highest Fundamental Frequency of females for age groups between 20-60 years



4. Lowest Fundamental Frequency (Flo) (Hz)

The results for Flo are presented in Table 21 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	118.18	188.19	12.77	44.52	91.99	77.28	145.57	245.69	53.58	168.40
30-40	117.63	183.21	15.44	37.63	88.54	75.16	163.28	241.11	74.74	165.95
40-50	113.86	172.43	15.97	38.48	68.04	92.49	144.06	229.08	76.02	136.59
50-60	115.93	173.27	18.95	36.65	68.02	88.12	153.71	245.66	85.69	157.54

The mean Flo for males in the age group of 20-30 years was found to be 118.18 (SD = 12.77) whereas in females it was 188.19 (SD = 44.52). The range of Flo in males was observed as 53.58 and in females it was 168.40. The minimum Flo in males was 91.99 and in females it was 77.28. The maximum Flo in males was 145.57 and 245.69 in females. The mean Flo for males in the age group of 30-40 years was found to be 117.63 (SD = 15.44) whereas in females it was 183.21 (SD = 37.63). The range of Flo in males was observed as 74.74 and in females it was 165.95. The minimum Flo in males was 88.54 and in females it was 75.16. The maximum Flo in males was 163.28 and 241.11 in females. The mean Flo for males in the age group of 40-50 years was found to be 113.86

(SD = 15.97) whereas in females it was 172.43 (SD = 172.43). The range of Flo in males was observed as 76.02 and in females it was 136.59. The minimum Flo in males was 68.04 and in females it was 92.49. The maximum Flo in males was 144.06 and 229.08 in females. The mean Flo for males in the age group of 50-60 years was found to be 115.93 (SD = 18.95) whereas in females it was 173.27 (SD = 36.65). The range of Flo in males was observed as 85.69 and in females it was 157.54. The minimum Flo in males was 68.02 and in females it was 88.12. The maximum Flo in males was 153.71 and 245.66 in females. No significant main effect of age was observed in either females ($F(3,193) = 1.88$, $p < .135$) or males ($F(3,196) = .74$, $p < .52$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=179.4, SD=39.75) and males (M=116.4, SD=15.9) reveal significant difference t(395)=20.78, p=.00

Fig 43: Lowest Fundamental Frequency of males for age groups between 20-60 years

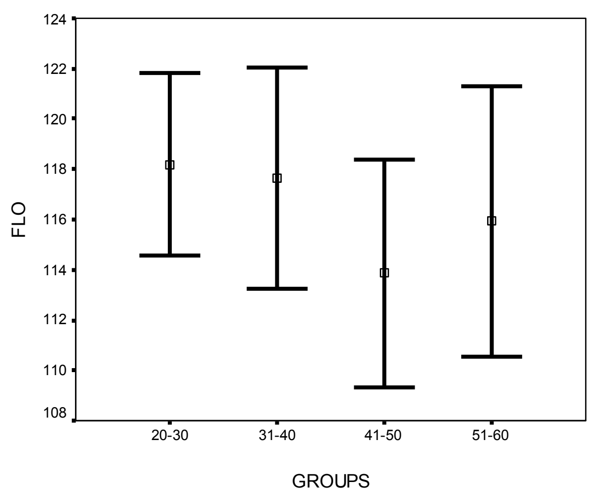
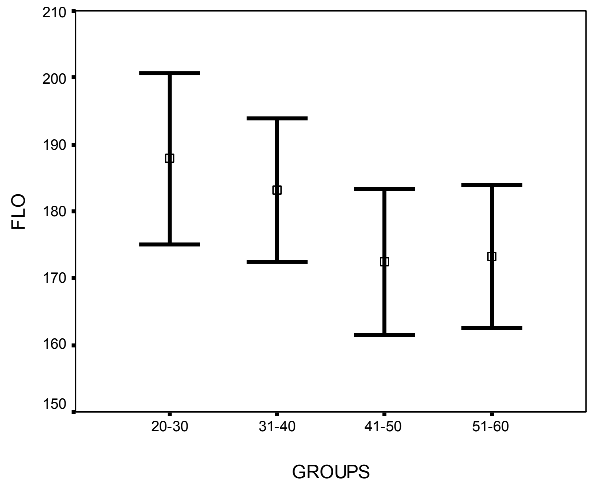


Fig 44: Lowest Fundamental Frequency of females for age groups between 20-60 years



5. Standard Deviation of F0 (STD) (Hz)

The results for STD are presented in Table 22 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	6.95	8.54	11.63	13.22	.62	1.21	49.66	56	49.04	54.79
30-40	4.19	11.36	5.93	16.68	.31	1.71	34.12	62.42	33.81	60.71
40-50	7.20	18.62	10.99	19.70	.60	1.52	51.35	67.44	50.75	65.93
50-60	4.99	11.76	10.53	13.74	.85	1.21	58.70	58.93	57.84	57.72

The mean STD for males in the age group of 20-30 years was found to be 6.95 (SD = 11.63) whereas in females it was 8.54 (SD = 13.22). The range of STD in males was observed as 49.04 and in females it was 49.04. The minimum STD in males was .62 and in females it was 1.21. The maximum STD in males was 49.66 and 56 in females. The mean STD for males in the age group of 30-40 years was found to be 4.19 (SD = 5.93) whereas in females it was 11.36 (SD = 16.68). The range of STD in males was observed as 33.81and in females it was 60.71. The minimum STD in males was .31 and in females it was 1.71. The maximum STD in males was 34.12 and 62.42 in females. The mean STD for males in the age group of 40-50 years was found to be 7.20 (SD =

10.99) whereas in females it was 18.62 (SD = 19.70). The range of STD in males was observed as 50.75 and in females it was 65.93. The minimum STD in males was .60 and in females it was 1.52. The maximum STD in males was 51.35 and 67.44 in females. The mean STD for males in the age group of 50-60 years was found to be 4.99 (SD = 10.53) whereas in females it was 11.76 (SD = 13.74). The range of STD in males was observed as 57.84 and in females it was 57.72. The minimum STD in males was .85 and in females it was 1.21. The maximum STD in males was 58.70 and 58.93 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,193) = 3.53$, $p < .02$) while no significant difference was observed in males ($F(3,196) = 1.084$, $p < .35$). The independent t-test between the females (M=12.59, SD=16.39) and males (M=8.33, SD=22.5) reveal significant difference t(395)=2.15, $p=.03$

Fig 45: Standard Deviation of Fundamental Frequency of males for age groups between 20-60 years

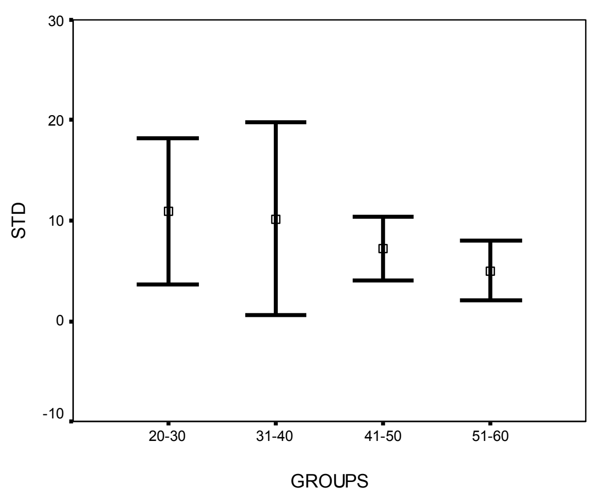
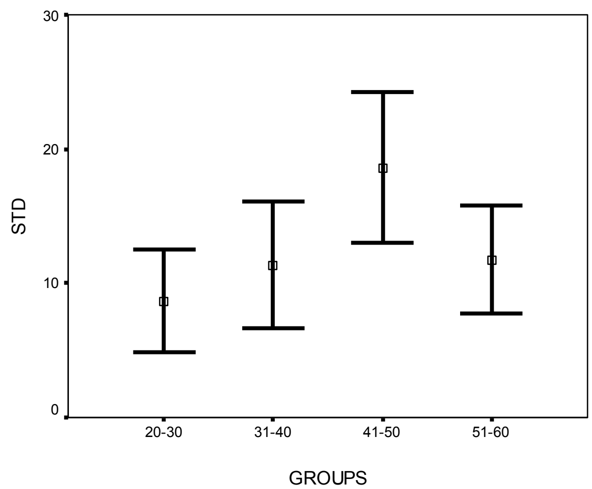


Fig 46: Standard Deviation of Fundamental Frequency of females for age groups between 20-60 years



6. Coefficient of Variation of F0 (vFo) (%)

The results for vFo are presented in Table 23 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	8.00	4.29	17.06	7.29	.53	.55	83.47	35.33	82.94	34.78
30-40	3.07	5.99	3.65	9.33	.27	.85	20.35	38.96	20.08	38.11
40-50	6.15	9.55	9.25	10.44	.63	.72	38.35	34.75	37.72	34.03
50-60	4.68	6.29	9.72	7.84	.76	.55	50.24	32.98	49.48	32.43

The mean vF_O for males in the age group of 20-30 years was found to be 8 (SD = 17.06) whereas in females it was 8.54 (SD = 4.29). The range of vF_O in males was observed as 82.94 and in females it was 34.78. The minimum vF_O in males was .53 and in females it was .55. The maximum vF_O in males was 83.47 and 35.33 in females. The mean vF_O for males in the age group of 30-40 years was found to be 3.07 (SD = 3.65) whereas in females it was 5.99 (SD = 9.33). The range of vF_O in males was observed as 20.08 and in females it was 38.11. The minimum vF_O in males was .27 and in females it was .85. The maximum vF_O in males was 20.35 and 38.96 in females. The mean vF_O for males in the age group of 40-50 years was found to be 6.15 (SD = 9.25) whereas in females it was 9.55 (SD = 10.44). The range of vF_O in males was observed as 37.72 and in females it was 34.03. The minimum vF_O in males was .63 and in females it was .72. The maximum vF_O in males was 38.35 and 34.75 in females. The mean vF_O for males in the age group of 50-60 years was found to be 4.68 (SD = 9.72) whereas in females it was 6.29 (SD = 7.84). The range of vF_O in males was observed as 49.48 and in females it was 32.43. The minimum vF_O in males was .76 and in females it was .55. The maximum vF_O in males was 50.24 and 32.98 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,193) = 3.1$, $p < .03$) while no significant difference was observed in males ($F(3,196) = 1.81$, $p < .14$). The independent t-test between the females (M=6.54, SD=8.97) and males (M=6.78, SD=16.5) did not reveal significant difference $t(395)= -0.18$, $p=.8$

Fig 47: Coefficient of Variation of Fundamental Frequency of males for age groups between 20-60 years

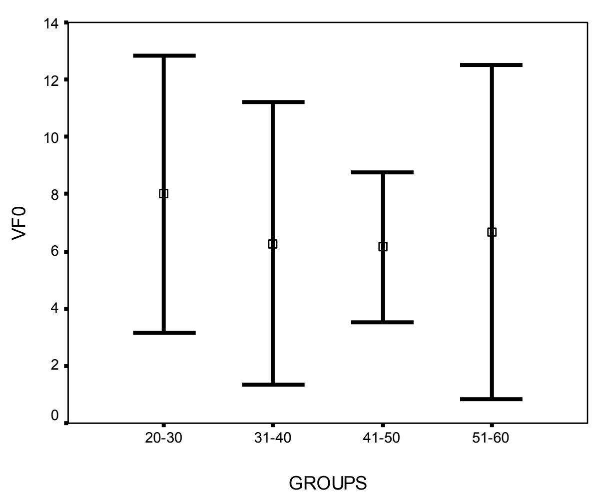
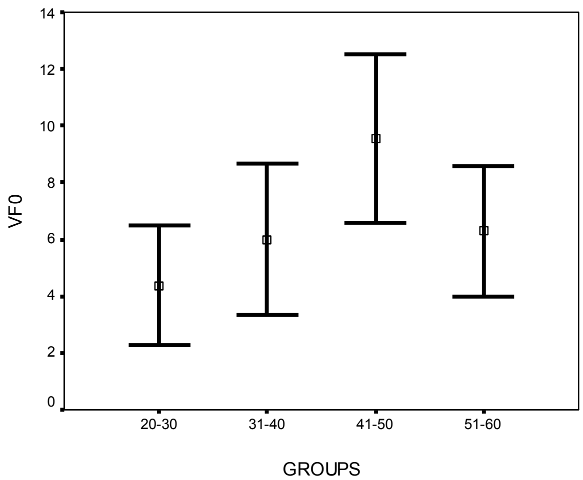


Fig 48: Coefficient of Variation of Fundamental Frequency of females for age groups between 20-60 years



7. Coefficient of Variation of Amplitude (vAm) (%)

The results for vAm are presented in Table 24 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	31.66	21.69	23.98	17.43	5.25	5.77	73.93	74.89	68.68	69.12
30-40	48.15	39.20	18.40	22.80	10.90	3.29	77.05	71.21	66.14	67.92
40-50	51.02	42.18	19.69	17.45	7.46	4.31	83.22	72.99	75.77	68.68
50-60	44.61	39.81	19.65	17.78	6.01	13.44	73.27	72.99	67.26	59.55

The mean vAm for males in the age group of 20-30 years was found to be 31.66 (SD = 23.98) whereas in females it was 21.69 (SD = 17.43). The range of vAm in males was observed as 68.68 and in females it was 69.12. The minimum vAm in males was 5.25 and in females it was 5.77. The maximum vAm in males was 73.93 and 74.89 in females. The mean vAm for males in the age group of 30-40 years was found to be 48.15 (SD = 18.40) whereas in females it was 39.20 (SD = 22.80). The range of vAm in males was observed as 66.14 and in females it was 67.92. The minimum vAm in males was 10.90 and in females it was 3.29. The maximum vAm in males was 77.05 and 71.21 in females. The mean vAm for males in the age group of 40-50 years was found to be 51.02 (SD = 19.69) whereas in females it was 42.18 (SD = 17.45). The range of vAm in males was observed as 75.77 and in females it was 68.68. The minimum vAm in males was 7.46 and in females it was 4.31. The maximum vAm in males was 83.22 and 72.99 in females. The mean vAm for males in the age group of 50-60 years was found to be 44.61 (SD = 19.65) whereas in females it was 39.81 (SD = 17.78). The range of vAm in males was observed as 67.26 and in females it was 59.55. The minimum vAm in males was 6.01 and in females it was 13.44. The maximum vAm in males was 73.27 and 72.99 in females. There was a significant age effect in both females [$F(3,193)=12.3$, $p=.00$] and males [$F(3,196)=8.65$, $p=.00$] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=35.61, SD=20.66) and males (M=44.12, SD=22.63) reveal significant difference $t(395)= -3.91$, $p=.00$

Fig 49: Coefficient of Variation of Amplitude of males for age groups between 20-60 years

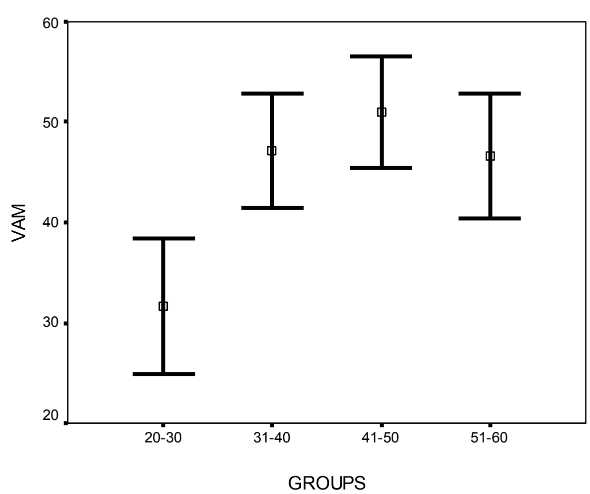
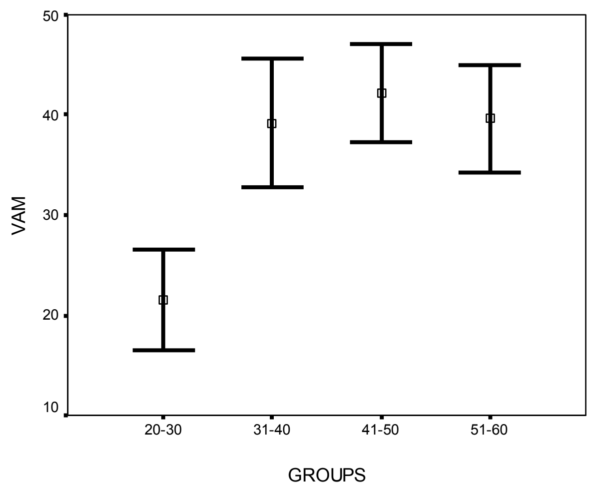


Fig 50: Coefficient of Variation of Amplitude of females for age groups between 20-60 years



Tremor Parameters

1. Magnitude Frequency Tremor (Mftr) (%)

The results for Mftr are presented in Table 25 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Femal e	Male	Fema le	Male	Fem ale
20-30	.60	.55	.48	.37	.21	.14	2.98	1.91	2.78	1.76
30-40	.61	.70	.35	.38	.18	.30	2.28	1.88	2.10	1.59
40-50	.69	.87	.41	.66	.24	.19	2.06	3.56	1.81	3.37
50-60	.70	.66	.41	.26	.22	.26	2.45	1.45	2.22	1.20

The mean Mftr for males in the age group of 20-30 years was found to be .60 (SD = .48) whereas in females it was .55 (SD = .37). The range of Mftr in males was observed as 2.78 and in females it was 1.76. The minimum Mftr in males was .21 and in females it was .14. The maximum Mftr in males was 2.98 and 1.91 in females. The mean Mftr for males in the age group of 30-40 years was found to be .61 (SD = .35) whereas in females it was .70 (SD = .38). The range of Mftr in males was observed as 2.10 and in females it was 1.59. The minimum Mftr in males was .18 and in females it was .30. The maximum Mftr in males was 2.28 and 1.88 in females. The mean Mftr for males in the age group of 40-50 years was found to be .69 (SD = .41)

whereas in females it was .87 (SD = .66). The range of Mftr in males was observed as 1.81 and in females it was 3.37. The minimum Mftr in males was .24 and in females it was .19. The maximum Mftr in males was 2.06 and 3.56 in females.
The mean Mftr for males in the age group of 50-60 years was found to be .70 (SD = .41) whereas in females it was .66 (SD = .26). The range of Mftr in males was observed as 2.22 and in females it was 1.20. The minimum Mftr in males was .22 and in females it was .26. The maximum Mftr in males was 2.45 and 1.45 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,193) = 4.3$, $p < .006$) while no significant difference was observed in males ($F(3,196) = .78$, $p < .5$). The independent t-test between the females (M=0.70, SD=0.46) and males (M=0.65, SD=0.42) did not reveal significant difference $t(395)=1.03$, $p=.3$

Fig 51: Magnitude Frequency Tremor of males for age groups between 20-60 years

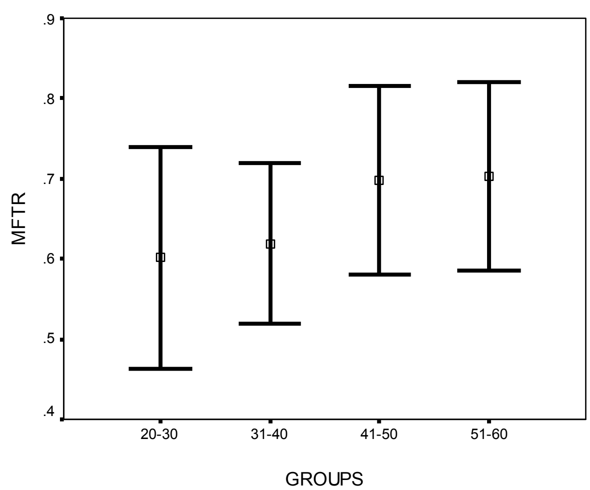
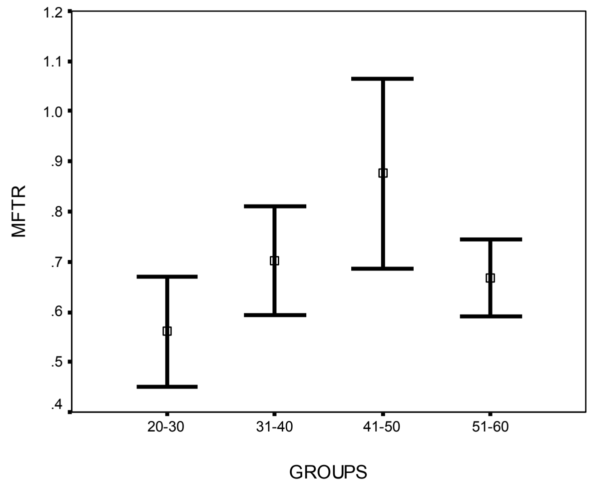


Fig 52: Magnitude Frequency Tremor of females for age groups between 20-60 years



2. Magnitude Amplitude Tremor (Matr) (%)

The results for Matr are presented in Table 26 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	4.13	3.22	1.51	1.12	1.88	1.66	9.41	6.40	7.53	4.73
30-40	4.45	4.52	1.57	1.80	1.92	1.76	8.57	8.81	6.64	7.06
40-50	4.29	5.16	1.88	1.78	2.10	1.59	12.44	9	10.34	7.41
50-60	4.36	4.71	2.15	1.52	1.88	2.25	11.60	8.24	9.73	5.98

The mean Matr for males in the age group of 20-30 years was found to be 4.13 (SD = 1.51) whereas in females it was 3.22 (SD = 1.12). The range of Matr in males was observed as 7.53 and in females it was 4.73. The minimum Matr in males was 1.88 and in females it was 1.66. The maximum Matr in males was 9.41 and 6.40 in females. The mean Matr for males in the age group of 30-40 years was found to be 4.45 (SD = 1.57) whereas in females it was 4.52 (SD = 1.80). The range of Matr in males was observed as 6.64 and in females it was 7.06. The minimum Matr in males was 1.92 and in females it was 1.76. The maximum Matr in males was 8.57 and 8.81 in females. The mean Matr for males in the age group of 40-50 years was found to be 4.29 (SD = 1.88) whereas in females it was 5.16 (SD = 1.78). The range of Matr in males was observed as 10.34 and in females it was 7.41. The minimum Matr in males was 2.10 and in females it was 1.59. The maximum Matr in males was 12.44 and 9 in females. The mean Matr for males in the age group of 50-60 years was found to be 4.36 (SD = 2.15) whereas in females it was 4.71 (SD = 1.52). The range of Matr in males was observed as 9.73 and in females it was 5.98. The minimum Matr in males was 1.88 and in females it was 2.25. The maximum Matr in males was 11.60 and 8.24 in females. There was a significant age effect in both females [F(3,193)=13.6, p=.00] and males [F(3,196)=68.6, p=.00] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=4.40, SD=1.73) and males (M=4.31, SD=1.79) did not reveal significant difference t(394)=0.51, *p*=.6

Fig 53: Magnitude Amplitude Tremor of males for age groups between 20-60 years

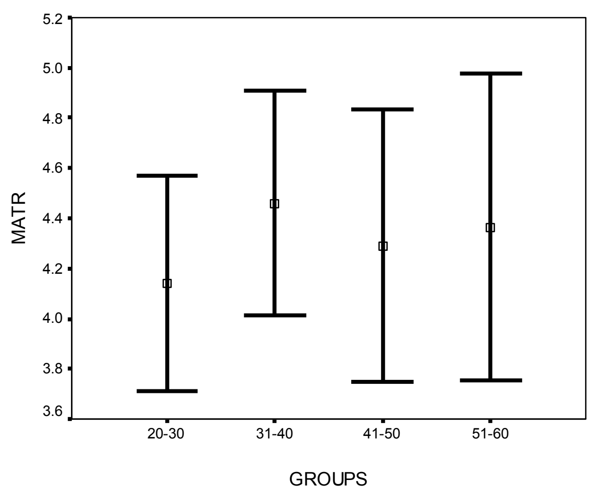
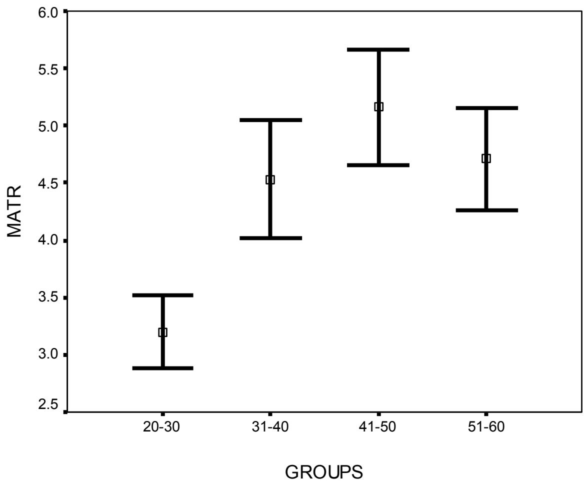


Fig 54: Magnitude Amplitude Tremor of females for age groups between 20-60 years



3. Rate of Frequency Tremor (Rftr) (Hz)

The results for Rftr are presented in Table 27 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	5.61	5.11	2.80	1.21	2.53	3.39	9.52	6.06	6.99	2.67
30-40	3.24	5.20	.86	3.25	2.02	1.85	4.65	10.53	2.63	8.67
40-50	5.46	6.17	.83	3.95	4.44	2.82	6.67	12.87	2.22	10.05
50-60	6.53	3.90	3.83	1.67	2.70	1.87	15.62	7.41	12.91	5.54

The mean Rftr for males in the age group of 20-30 years was found to be 5.61 (SD = 2.80) whereas in females it was 5.11 (SD = 1.21). The range of Rftr in males was observed as 6.99 and in females it was 2.67. The minimum Rftr in males was 2.53 and in females it was 3.39. The maximum Rftr in males was 9.52 and 6.06 in females. The mean Rftr for males in the age group of 30-40 years was found to be 3.24 (SD = .86) whereas in females it was 5.20 (SD = 3.25). The range of Rftr in males was observed as 8.67 and in females it was 7.06. The minimum Rftr in males was 2.02 and in females it was 1.85. The maximum Rftr in males was 4.65 and 10.53 in females. The mean Rftr for males in the age group of 40-50 years was found to be 5.46 (SD = .83) whereas in females it was 6.17 (SD = 3.95). The range of Rftr in males was observed as 2.22 and in females it was 10.05. The minimum Rftr in males was 4.44 and in females it was 2.82. The maximum Rftr in males was 6.67 and 12.87 in females. The mean Rftr for males in the age group of 50-60 years was found to be 6.53 (SD =

3.83) whereas in females it was 3.90 (SD = 1.67). The range of Rftr in males was observed as 12.91 and in females it was 5.54. The minimum Rftr in males was 2.70 and in females it was 1.87. The maximum Rftr in males was 15.62 and 7.41 in females. No significant main effect of age was observed in either females ($F(3,29) = .92$, $p < .4$) or males ($F(3,27) = 2.64$, $p < .7$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=5.03, SD=2.89) and males (M=5.22, SD=2.85) did not reveal significant difference t(62)= -0.26, p=.7

Fig 55: Rate of Frequency Tremor of males for age groups between 20-60 years

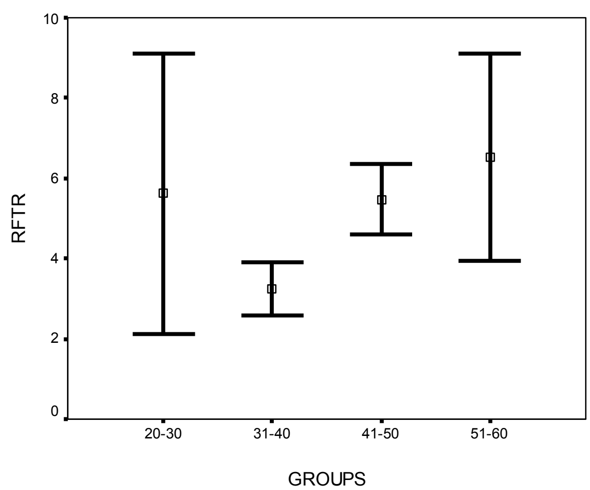
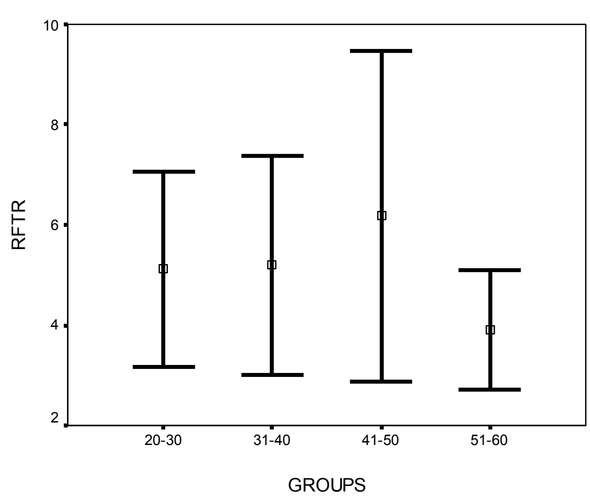


Fig 56: Rate of Frequency Tremor of females for age groups between 20-60 years



4. Rate of Amplitude Tremor (Ratr) (Hz)

The results for Ratr are presented in Table 28 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	3.63	4.00	1.80	1.81	1.94	1.98	8.70	7.14	6.75	5.16
30-40	2.27	5.04	.37	3.33	2	2	2.70	11.77	.70	9.77
40-50	2.83	3.48	.71	1.19	1.87	2.41	3.51	5.41	1.64	3
50-60	2.25	4.37	.86	2.48	.48	1.91	4	9.52	3.52	7.62

The mean Ratr for males in the age group of 20-30 years was found to be 3.63 (SD = 1.80) whereas in females it was 4 (SD = 1.81). The range of Ratr in males was observed as 6.75 and in females it was 5.16. The minimum Ratr in males was 1.94 and in females it was 1.98. The maximum Ratr in males was 8.70 and 7.14 in females. The mean Ratr for males in the age group of 30-40 years was found to be 2.27 (SD = .37) whereas in females it was 5.04 (SD = 3.33). The range of Ratr in males was observed as .70 and in females it was 3. The minimum Ratr in males was 1.87 and in females it was 2. The maximum Ratr in males was 2.70 and 11.77 in females. The mean Ratr for males in the age group of 40-50 years was found to be 2.83 (SD = .71) whereas in females it was 3.48 (SD = 1.19). The range of Ratr in males was observed as 1.64 and in females it was 10.05. The minimum Ratr in males was 4.44 and in females it was 2.41. The maximum Ratr in males was 3.51 and 5.41 in females. The mean Ratr for males in the age group of 50-60 years was found to be 2.25 (SD = .86) whereas in females it was 4.37 (SD = 2.48). The range of Ratr in males was observed as 3.52 and in females it was 7.62. The minimum Ratr in males was .48 and in females it was 1.91. The maximum Ratr in males was 4 and 9.52 in females. No significant main effect of age was observed in either females ($F(3,42) = .77$, $p < .52$) or males ($F(3,31) = 2.6$, $p < .07$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=4.36, SD=2.50) and males (M=2.93, SD=1.44) revealed significant difference t(79)=3.02, p=.003.

Fig 57: Rate of Amplitude Tremor of males for age groups between 20-60 years

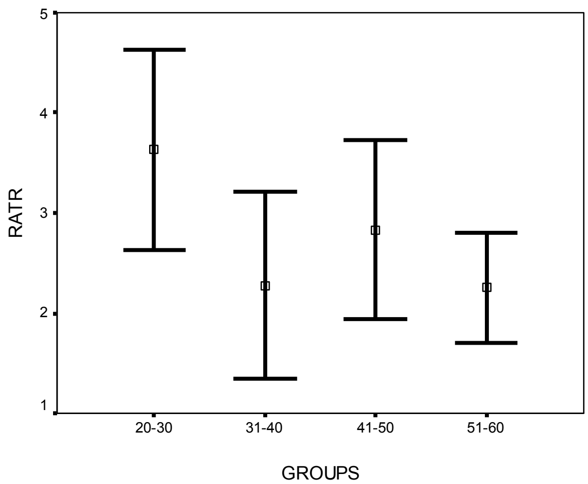
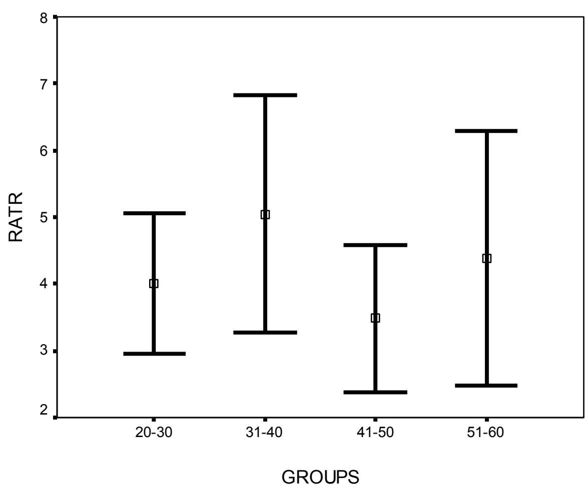


Fig 58: Rate of Amplitude Tremor of females for age groups between 20-60 years



5. Periodicity of Frequency Tremor (Pftr) (%)

The results for Pftr are presented in Table 29 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	46.84	47.97	20.03	15.04	22.67	26.50	76.95	61.54	54.28	35.04
30-40	28.71	37.59	11.63	18.30	11.70	16.02	51.16	72.28	39.46	56.26
40-50	37.26	60.65	21.88	79.07	22.04	10.38	76.95	262.59	54.91	252.22
50-60	33.88	28.30	20.52	13.25	4.85	10.38	68.53	47.01	63.68	36.63

The mean Pftr for males in the age group of 20-30 years was found to be 46.84 (SD = 20.03) whereas in females it was 47.97 (SD = 15.04). The range of Pftr in males was observed as 54.28 and in females it was 35.04. The minimum Pftr in males was 22.67 and in females it was 26.50. The maximum Pftr in males was 76.95 and 61.54 in females. The mean Pftr for males in the age group of 30-40 years was found to be 28.71 (SD = 11.63) whereas in females it was 37.59 (SD = 18.30). The range of Pftr in males was observed as 39.46 and in females it was 56.26. The minimum Pftr in males was 11.70 and in females it was 16.02. The maximum Pftr in males was 51.16 and 72.28 in females. The mean Pftr for males in the age group of 40-50 years was found to be 37.26 (SD = 21.88) whereas in females it was 60.65 (SD = 79.07). The range of Pftr in males was observed as 54.91 and in females it was 252.22. The minimum Pftr in males was 22.04 and in females it was 10.38. The maximum Pftr in males was 76.95 and 262.59 in females. The mean Pftr for males in the age group of 50-60 years was found to be 33.88 (SD = 20.52) whereas in females it was 28.30 (SD = 13.25). The range of Pftr in males was observed as 63.68 and in females it was 36.63. The minimum Pftr in males was 4.85 and in females it was 10.38. The maximum Pftr in males was 68.53 and 47.01 in females. No significant main effect of age was observed in either females ($F(3,30) = .96$, $p < .42$) or males ($F(3,27) = 1.06$, $p < .4$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=42.19, SD=42.99) and males (M=35.13, SD=18.62) did not reveal significant difference $t(63)=0.84$, $p=.4$.

Fig 59: Periodicity of Frequency Tremor of males for age groups between 20-60 years

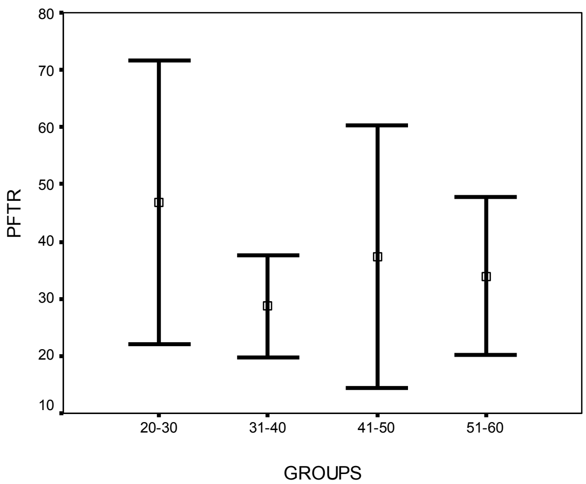
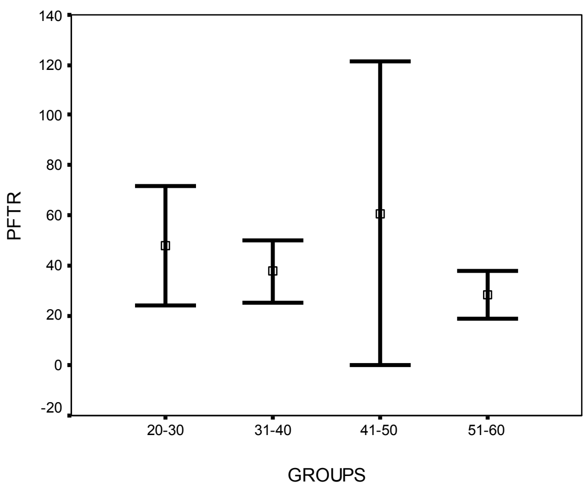


Fig 60: Periodicity of Frequency Tremor of females for age groups between 20-60 years



6. Periodicity of Amplitude Tremor (Patr) (%)

The results for Patr are presented in Table 30 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Femal e
20-30	39.06	40.29	23.46	15.01	13.51	13.04	79.58	60.44	66.07	47.40
30-40	52.93	34.73	37.77	21.10	10.36	11.15	82.44	77.94	72.09	66.79
40-50	26.64	26.97	10.43	25.77	16.70	3.81	39.30	77.95	22.60	74.15
50-60	32.84	50.68	13.10	21.61	15.61	22.33	58.27	78.49	42.66	56.16

The mean Patr for males in the age group of 20-30 years was found to be 39.06 (SD = 23.46) whereas in females it was 40.29 (SD = 15.01). The range of Patr in males was observed as 66.07 and in females it was 47.40. The minimum Patr in males was 13.51 and in females it was 13.04. The maximum Patr in males was 79.58 and 60.44 in females. The mean Patr for males in the age group of 30-40 years was found to be 52.93 (SD = 37.77) whereas in females it was 34.73 (SD = 21.10). The range of Patr in males was observed as 72.09 and in females it was 66.79. The minimum Patr in males was 10.36 and in females it was 11.15. The maximum Patr in males was 82.44 and 77.94 in females. The mean Patr for males in the age group of 40-50 years was found to be 26.64 (SD = 10.43) whereas in females it was 26.97 (SD = 25.77). The range of Patr in males was observed as 22.60 and in females it was 74.15. The minimum Patr in males was 16.70 and in females it was 3.81. The maximum Patr in males was 39.30 and 77.95 in females. The mean Patr for males in the age group of 50-60 years was found to be 32.84 (SD = 13.10) whereas in females it was 50.68 (SD = 21.61). The range of Patr in males was observed as 42.66 and in females it was 56.16. The minimum Patr in males was 15.61 and in females it was 22.33. The maximum Patr in males was 58.27 and 78.49 in females. No significant main effect of age was observed in either females ($F(3,43) = 2.12$, $p < .11$) or males ($F(3,30) = 1.21$, $p < .32$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=38.12, SD=21.19) and males (M=36.45, SD=20.78) did not reveal significant difference t(79)=0.35, p=.7

Fig 61: Periodicity of Amplitude Tremor of males for age groups between 20-60 years

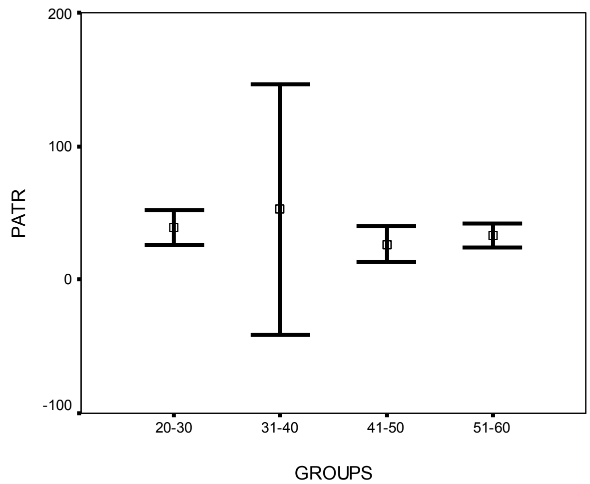
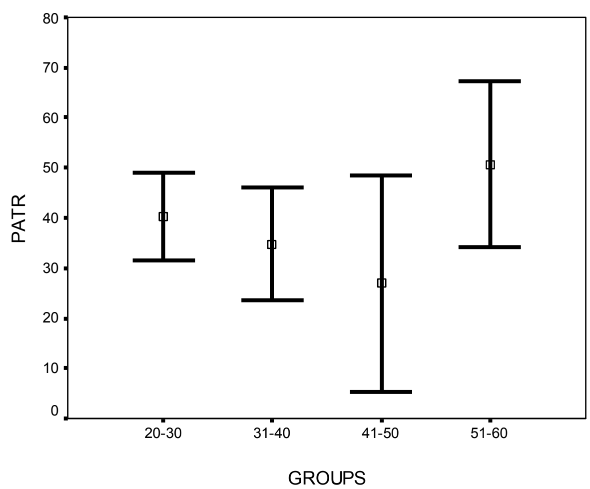


Fig 62: Periodicity of Amplitude Tremor of females for age groups between 20-60 years



Intonation Stimulability Parameters

1. Running Speech Fundamental Frequency (rFo) (Hz)

The results for rFo are presented in Table 31 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	137.02	235.32	14.88	24.97	110.09	177.42	176.81	294.14	66.71	116.72
30-40	140.48	226.23	17.21	24.29	105.83	155.98	184.72	275.86	78.89	119.88
40-50	140.23	215.76	19.91	27.16	96.11	167.05	180.03	266.08	83.93	99.03
50-60	143.08	216.09	21.67	29.91	108.25	164.06	181.58	283.89	73.32	119.83

The mean rFo for males in the age group of 20-30 years was found to be 137.02 (SD = 14.88) whereas in females it was 235.32 (SD = 24.97). The range of rFo in males was observed as 66.71 and in females it was 116.72. The minimum rFo in males was 110.09 and in females it was 177.42. The maximum rFo in males was 176.81 and 294.14 in females. The mean rFo for males in the age group of 30-40 years was found to be 140.48 (SD = 17.21) whereas in females it was 226.23 (SD = 24.29). The range of rFo in males was observed as 78.89 and in females it was 119.88. The minimum rFo in males was 105.83 and in females it was 155.98. The maximum rFo in males was 184.72 and 275.86 in females. The mean rFo for males in the age group of 40-50 years was found to be 140.23 (SD = 19.91) whereas in females it was 215.76 (SD = 27.16). The range of rFo in males was observed as 83.93 and in females it was 99.03. The minimum rFo in males was 96.11 and in females it was 167.05. The maximum rFo in males was 180.03 and 266.08 in females. The mean rFo for males in the age group of 50-60 years was found to be 143.08 (SD = 21.67) whereas in females it was 216.09 (SD = 29.91). The range of rFo in males was observed as 73.32 and in females it was 119.83. The minimum rFo in males was 108.25 and in females it was 164.06. The maximum rFo in males was 181.58 and 283.89 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,195) = 6.1$, $p < .001$) while no significant difference was observed in males ($F(3,194) = .88$, $p < .45$). The independent t-test between the females (M=223.4, SD=27.67) and males (M=140.19, SD=18.56) reveal significant difference $t(395)=35.2$, $p=.00$

Fig 63: Running Speech Fund. Frequency of males for age groups between 20-60 years

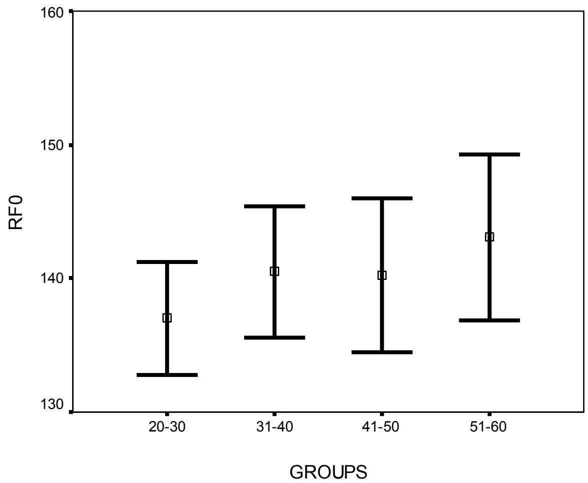
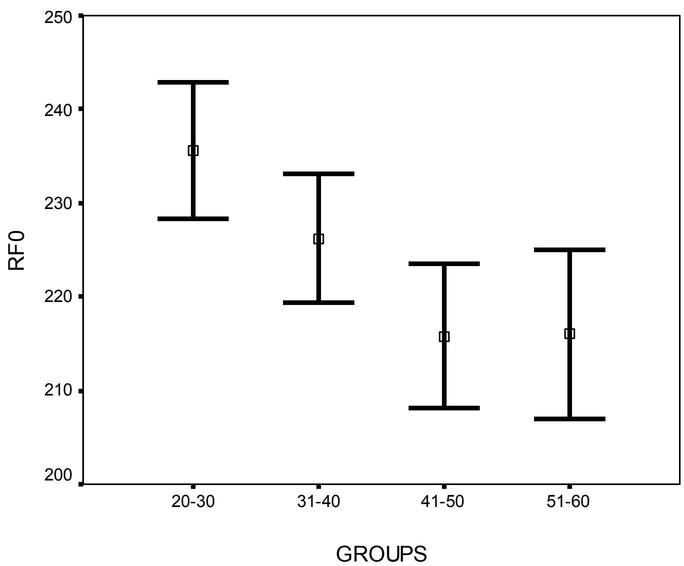


Fig 64: Running Speech Fund. Frequency of females for age groups between 20-60 years



2. Running Speech Pitch Period (rTo) (ms)

The results for rTo are presented in Table 32 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	7.37	4.29	.77	.48	5.66	3.40	9.08	5.64	3.43	2.24
30-40	7.22	4.47	.90	.50	5.41	3.63	9.45	6.41	4.04	2.79
40-50	7.27	4.70	1.04	.59	5.56	3.76	10.41	5.99	4.85	2.23
50-60	7.15	4.68	1.09	.60	5.54	3.52	9.24	6.10	3.70	2.57

The mean rTo for males in the age group of 20-30 years was found to be 7.37 (SD = .77) whereas in females it was 4.29 (SD = .48). The range of rTo in males was observed as

3.43 and in females it was 2.24. The minimum rTo in males was 5.66 and in females it was 3.40. The maximum rTo in males was 9.08 and 5.64 in females. The mean rTo for males in the age group of 30-40 years was found to be 7.22 (SD = .90) whereas in females it was 4.47 (SD = .50). The range of rTo in males was observed as 4.04 and in females it was 2.79. The minimum rTo in males was 5.41 and in females it was 3.63. The maximum rTo in males was 9.45 and 6.41 in females. The mean rTo for males in the age group of 40-50 years was found to be 7.27 (SD = 1.04) whereas in females it was 4.70 (SD = .59). The range of rTo in males was observed as 4.85 and in females it was 2.23. The minimum rTo in males was 5.56 and in females it was 3.76. The maximum rTo in males was 10.41 and 5.99 in females. The mean rTo for males in the age group of 50-60 years was found to be 7.15 (SD = 1.09) whereas in females it was 4.68 (SD = .60). The range of rTo in males was observed as 3.70 and in females it was 2.57. The minimum rTo in males was 5.54 and in females it was 3.52. The maximum rTo in males was 9.24 and 6.10 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,195) = 6.12$, $p < .001$) while no significant difference was observed in males ($F(3,194) = .48$, $p < .7$). The independent t-test between the females (M=4.54, SD=0.57) and males (M=7.26, SD=.95) reveal significant difference t(395)= -34.35, p=.00

Fig 65: Running Speech Pitch Period of males for age groups between 20-60 years

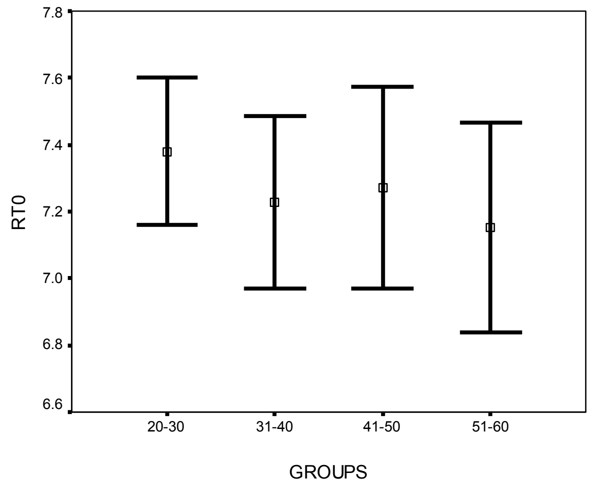
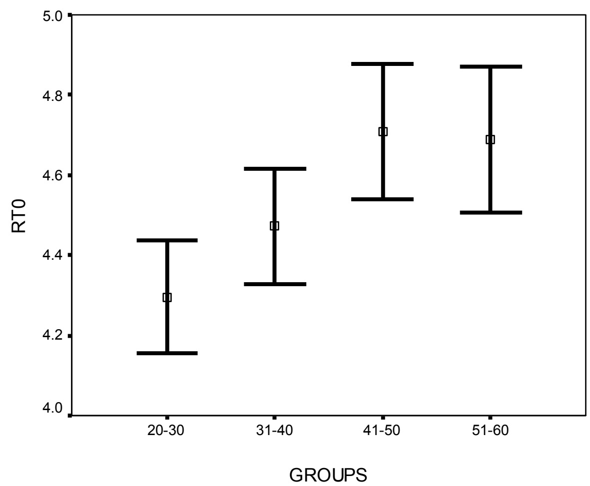


Fig 66: Running Speech Pitch Period of females for age groups between 20-60 years



3. Highest Fundamental Frequency (rFhi) (Hz)

The results for rFhi are presented in Table 33 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	180.97	304.18	46.68	42.92	21.90	219.15	354.58	396.01	332.69	176.87
30-40	210.18	296.56	64.74	51.57	130.07	212.74	400.03	396.21	269.96	183.47
40-50	241.49	310.73	81.81	56.34	133.90	220.36	400.46	399.55	266.57	179.19
50-60	221.25	291.01	74.03	57.56	135.97	208.68	400.64	413.47	264.67	204.80

The mean rFhi for males in the age group of 20-30 years was found to be 180.97 (SD = 46.68) whereas in females it was 304.18 (SD = 42.92). The range of rFhi in males was observed as 332.69 and in females it was 176.87. The minimum rFhi in males was 21.90 and in females it was 219.15. The maximum rFhi in males was 354.58 and 396.01 in females. The mean rFhi for males in the age group of 30-40 years was found to be 210.18 (SD = 64.74) whereas in females it was 296.56 (SD = 51.57). The range of rFhi in males was observed as 269.96 and in females it was 183.47. The minimum rFhi in males was 130.07 and in females it was 212.74. The maximum rFhi in males was 400.03 and 396.21 in females. The mean rFhi for males in the age group of 40-50 years was found to be 241.49 (SD = 81.81) whereas in females it was 310.73 (SD = 56.34). The range of rFhi in males was observed as 266.57 and in females it was 179.19. The minimum rFhi in males was 133.90 and in females it was 220.36. The maximum rFhi in males was 400.46 and 399.55 in females. The mean rFhi for males in the age group of 50-60 years was found to be 221.25 (SD = 74.03) whereas in females it was 291.01 (SD = 57.56). The range of rFhi in males was observed as 264.67 and in females it was 204.80. The minimum rFhi in males was 135.97 and in females it was 208.68. The maximum rFhi in males was 400.64 and 413.47 in females. The results of One-way ANOVA pointed towards no significant difference in mean across the different age groups in females ($F(3,195) = 1.34$, $p < .3$) while significant difference was observed in males ($F(3,194) = 6.83$, $p < .00$). The independent t-test between the females (M=300.67, SD=52.53) and males (M=217.2, SD=71.9) revealed significant difference $t(395)=13.22$, $p=.00$.

Fig 67: Highest Fundamental Frequency of males for age groups between 20-60 years

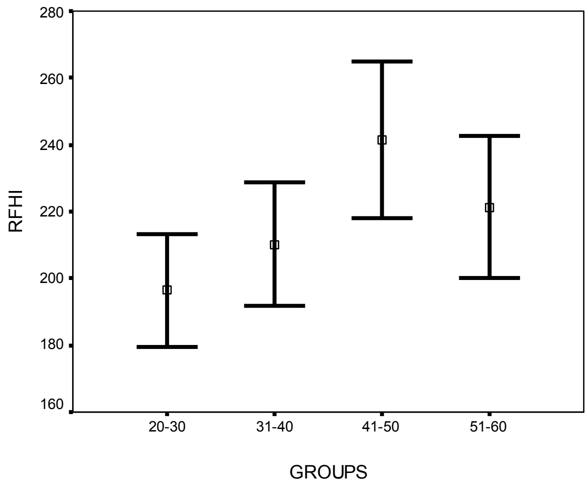
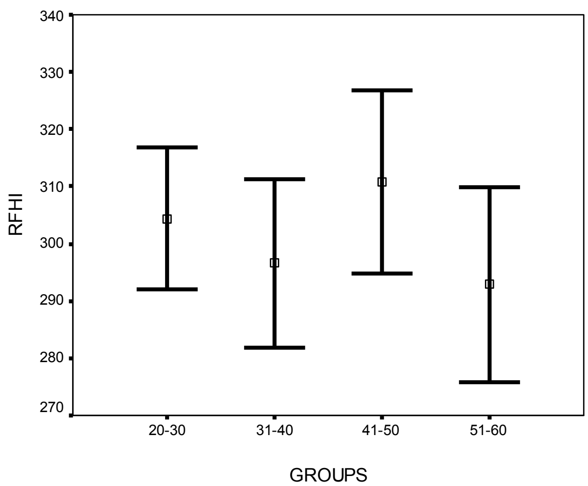


Fig 68: Highest Fundamental Frequency of females for age groups between 20-60 years



4. Lowest Fundamental Frequency (rFlo) (Hz)

The results for rFlo are presented in Table 34 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	113.16	189.03	14.95	37.26	80.87	95.99	148.03	240.60	67.16	144.61
30-40	111.42	182.12	16.44	30.72	75.77	95.60	148.71	226.23	72.94	130.63
40-50	111.83	167.55	21.40	42.48	74.21	68.18	168.86	226.23	94.65	158.04
50-60	112.81	179.94	20.33	40.47	68.29	83.48	149.87	299.38	81.58	215.90

The mean rFlo for males in the age group of 20-30 years was found to be 113.16 (SD = 14.95) whereas in females it was 189.03 (SD = 37.26). The range of rFlo in males was observed as 67.16 and in females it was 144.61. The minimum rFlo in males was 80.87 and in females it was 95.99. The maximum rFlo in males was 148.03 and 240.60 in females. The mean rFlo for males in the age group of 30-40 years was found to be 111.42 (SD = 16.44) whereas in females it was 182.12 (SD = 30.72). The range of rFlo in males was observed as 72.94 and in females it was 130.63. The minimum rFlo in males was 75.77 and in females it was 95.60. The maximum rFlo in males was 148.71 and 226.23 in females. The mean rFlo for males in the age group of 40-50 years was found to be 111.83 (SD = 21.40) whereas in females it was 167.55 (SD = 42.48). The range of rFlo in males was observed as 94.65 and in females it was 158.04. The minimum rFlo in males was 74.21 and in females it was 68.18. The maximum rFlo in males was 168.86 and 226.23 in females. The mean rFlo for males in the age group of 50-60 years was found to be 112.81 (SD = 20.33) whereas in females it was 179.94 (SD = 40.47). The range of rFlo in males was observed as 81.58 and in females it was 215.90. The minimum rFlo in males was 68.29 and in females it was 83.48. The maximum rFlo in males was 149.87 and 299.38 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,195) = 2.8$, $p < .04$) while no significant difference was observed in males ($F(3,194) = .097$, $p < .96$). The independent t-test between the females (M=176.65, SD=38.75) and males (M=111.8, SD=18.14) revealed significant difference $t(395)=21.34$, $p=.00$

Fig 69: Lowest Fundamental Frequency of males for age groups between 20-60 years

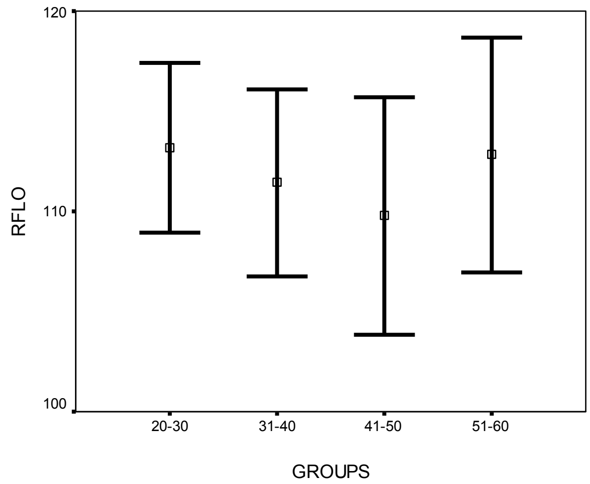
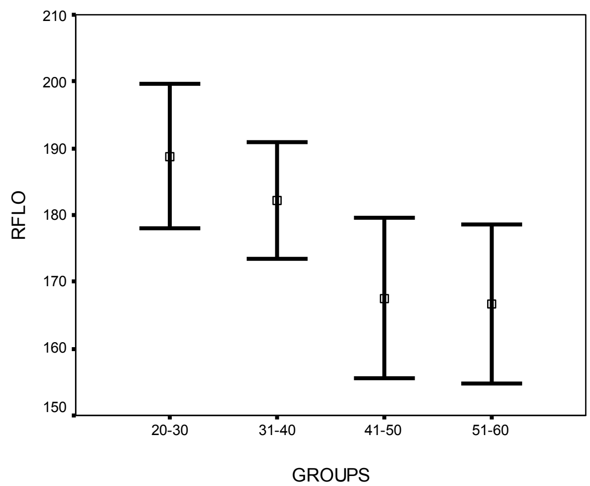


Fig 70: Lowest Fundamental Frequency of males for age groups between 20-60 years



5. Standard Deviation of Fundamental Frequency (rSTD) (Hz)

The results for rSTD are presented in Table 35 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	15.11	24.95	9.90	10.97	5.43	11.91	63.38	58.70	57.96	46.79
30-40	17.94	24.25	11.28	12.70	6.52	6.85	63.07	64.52	56.54	57.67
40-50	23.66	26.27	17.24	12.04	6.11	7.61	78.52	54.62	72.41	47.01
50-60	19.33	22.70	15.49	10.85	5.43	6.91	89.86	56.25	84.43	49.34

The mean rSTD for males in the age group of 20-30 years was found to be 15.11 (SD = 9.90) whereas in females it was 24.95 (SD = 10.97). The range of rSTD in males was observed as 57.96 and in females it was 46.79. The minimum rSTD in males was 5.43 and in females it was 11.91. The maximum rSTD in males was 63.38 and 58.70 in females. The mean rSTD for males in the age group of 30-40 years was found to be 17.94 (SD = 11.28) whereas in females it was 24.25 (SD = 12.70). The range of rSTD in males was observed as 56.54 and in females it was 57.67. The minimum rSTD in males was 6.52 and in females it was 6.85. The maximum rSTD in males was 63.07 and 64.52 in females. The mean rSTD for males in the age group of 40-50 years was found to be 23.66 (SD = 17.24) whereas in females it was 26.27 (SD = 12.04). The range of rSTD in males was observed as 72.41 and in females it was 47.01. The minimum rSTD in males was 6.11 and in females it was 7.61. The maximum rSTD in males was 78.52 and 54.62 in females. The mean rSTD for males in the age group of 50-60 years was found to be 19.33 (SD = 15.49) whereas in females it was 22.70 (SD = 10.85). The range of rSTD in males was observed as 84.43 and in females it was 49.34. The minimum rSTD in males was 5.43 and in females it was 6.91. The maximum rSTD in males was 89.86 and 56.25 in females. The results of One-way ANOVA pointed towards no significant difference in mean across the different age groups in females ($F(3,195) = 0.8$, $p < .5$) while significant difference was observed in males ($F(3,194) = 3.3$, $p < .02$). The independent t-test between the females (M=24.56, SD=11.66) and males (M=19.00, SD=14.02) revealed significant difference $t(395)=4.3$, $p=.00$

Fig 71: Standard Deviation of Fundamental Frequency of males for age groups between 20-60 years

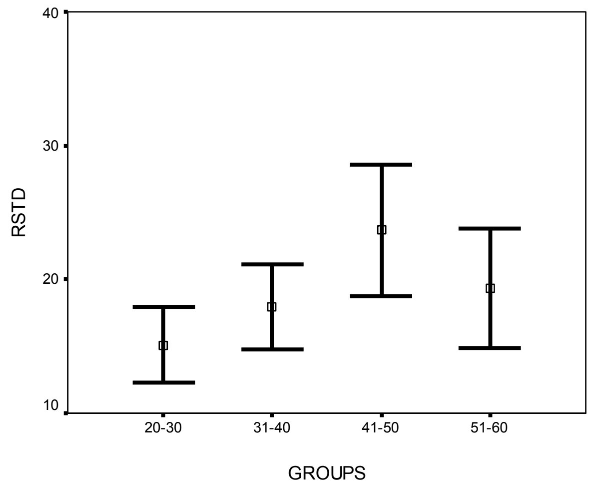
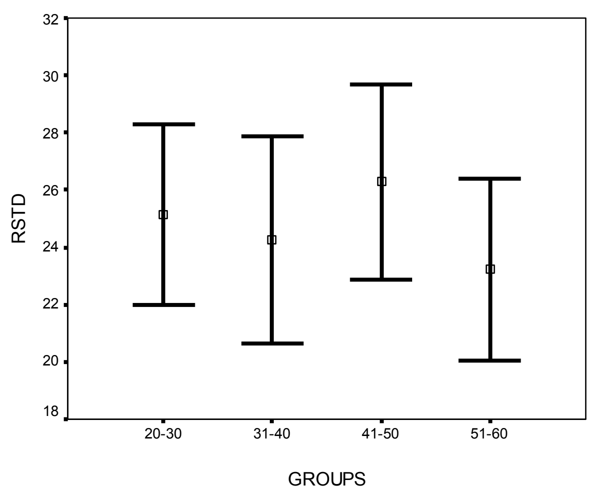


Fig 72: Standard Deviation of Fundamental Frequency of males for age groups between 20-60 years



6. Frequency Variability (rvFo) (%)

The results for rvFo are presented in Table 36 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	10.93	10.82	6.94	5.60	3.98	4.81	46.44	32.62	42.46	27.81
30-40	12.83	10.57	8.06	5.16	4.37	3.48	44.59	29.56	40.22	26.07
40-50	17.01	12.45	12.32	6.34	4.84	3.57	52.42	29.67	47.58	26.10
50-60	13.69	10.58	10.91	5.33	4.01	3.20	57.07	30.53	53.06	27.33

The mean rvFo for males in the age group of 20-30 years was found to be 10.93 (SD = 6.94) whereas in females it was 10.82 (SD = 5.60). The range of rvFo in males was observed as 42.46 and in females it was 27.81. The minimum rvFo in males was 3.98 and in females it was 4.81. The maximum rvFo in males was 46.44 and 32.62 in females. The mean rvFo for males in the age group of 30-40 years was found to be 12.83 (SD = 8.06) whereas in females it was 10.57 (SD = 5.16). The range of rvFo in males was observed as 40.22 and in females it was 26.07. The minimum rvFo in males was 4.37 and in females it was 3.48. The maximum rvFo in males was 44.59 and 29.56 in females. The mean rvFo for males in the age group of 40-50 years was found to be 17.01 (SD = 12.32) whereas in females it was 12.45 (SD = 6.34). The range of rvFo in males was observed as 47.58 and in females it was 26.10. The minimum rvFo in males was 4.84 and in females it was 3.57. The maximum rvFo in males was 52.42 and 29.67 in females. The mean rvFo for males in the age group of 50-60 years was found to be 13.69 (SD = 10.91) whereas in females it was 10.58 (SD = 5.33). The range of rvFo in males was observed as 53.06 and in females it was 27.33. The minimum rvFo in males was 4.01and in females it was 3.20. The maximum rvFo in males was 57.07 and 30.53 in females. The results of One-way ANOVA pointed towards no significant difference in mean across the different age groups in females ($F(3,195) = 1.3$, $p < .3$) while significant difference was observed in males ($F(3,194) = 3.33$, $p < .02$). The independent t-test between the females (M=11.11, SD=5.64) and males (M=13.6, SD=9.95) revealed significant difference t(395)= -3.07, p=.002

Fig 73: Frequency Variability of males for age groups between 20-60 years

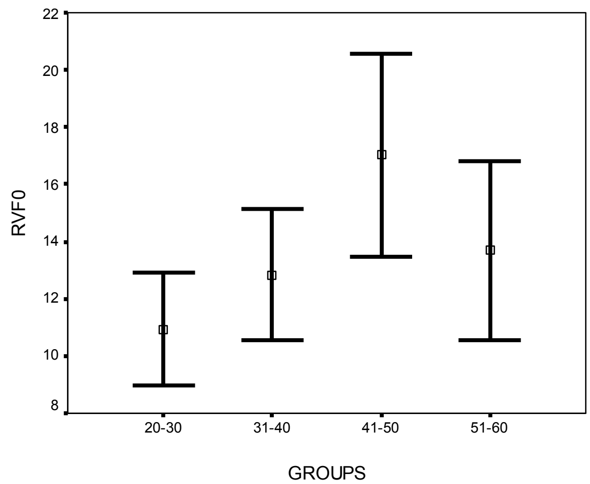
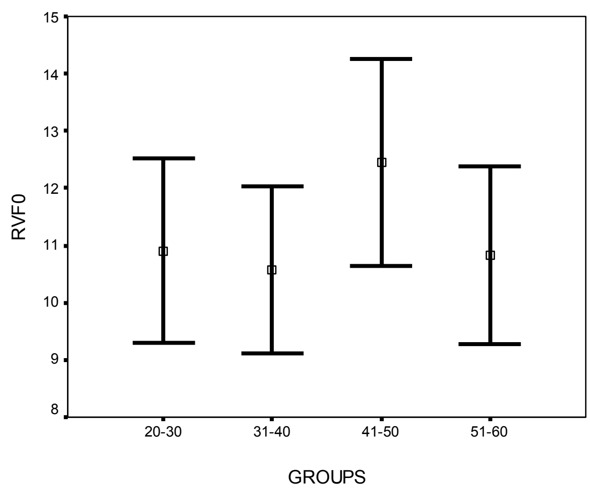


Fig 74: Frequency Variability of males for age groups between 20-60 years



7. Amplitude Variability (rvAm) (%)

The results for rvAm are presented in Table 37 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	32.87	30.32	9.76	5.60	17.20	11.98	82.20	41.90	65	29.91
30-40	33.33	31.57	7.18	8.83	19.55	5.19	53.70	52.36	34.15	47.17
40-50	36.00	33.34	7.50	8.04	19.53	5.19	55.54	59.23	36.01	54.04
50-60	33.69	35.00	6.78	8.36	14.88	20.19	48.87	71.31	33.99	51.12

The mean rvAm for males in the age group of 20-30 years was found to be 32.87 (SD = 9.76) whereas in females it was 30.32 (SD = 5.60). The range of rvAm in males was observed as 65 and in females it was 29.91. The minimum rvAm in males was 17.20 and in females it was 11.98. The maximum rvAm in males was 82.20 and 41.90 in females. The mean rvAm for males in the age group of 30-40 years was found to be 33.33 (SD = 7.18) whereas in females it was 31.57 (SD = 8.83). The range of rvAm in males was observed as 34.15 and in females it was 47.17. The minimum rvAm in males was 19.55 and in females it was 5.19. The maximum rvAm in males was 53.70 and 52.36 in females. The mean rvAm for males in the age group of 40-50 years was found to be 36 (SD = 7.50) whereas in females it was 33.34 (SD = 6.34). The range of rvAm in males was observed as 36.01 and in females it was 54.04. The minimum rvAm in males was 19.53 and in females it was 5.19. The maximum rvAm in males was 55.54 and 59.23 in females. The mean rvAm for males in the age group of 50-60 years was found to be 33.69 (SD = 6.78) whereas in females it was 35 (SD = 8.36). The range of rvAm in males was observed as 33.99 and in females it was 51.12. The minimum rvAm in males was 14.88 and in females it was 20.19. The maximum rSTD in males was 48.87 and 71.31 in females. The results of One-way ANOVA pointed towards significant difference in mean across the different age groups in females ($F(3,195) = 3.4$, $p < .02$) while no significant difference was observed in males ($F(3,194) = 1.53$, $p < .2$). The independent t-test between the females (M=32.55, SD=7.95) and males (M=13.97, SD=7.93) did not reveal significant difference t(395)= -1.78, p=.07

Fig 75: Amplitude Variability of males for age groups between 20-60 years

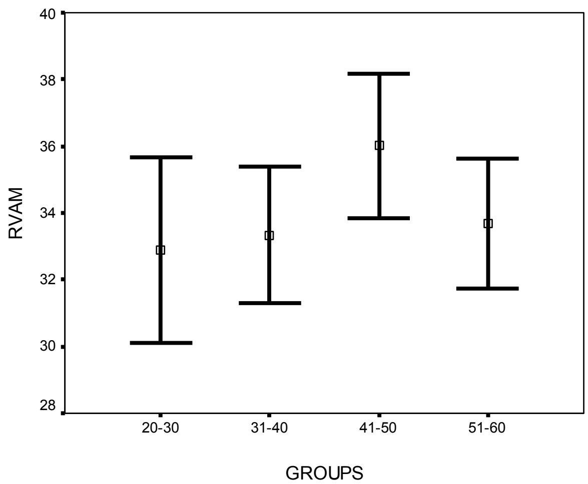
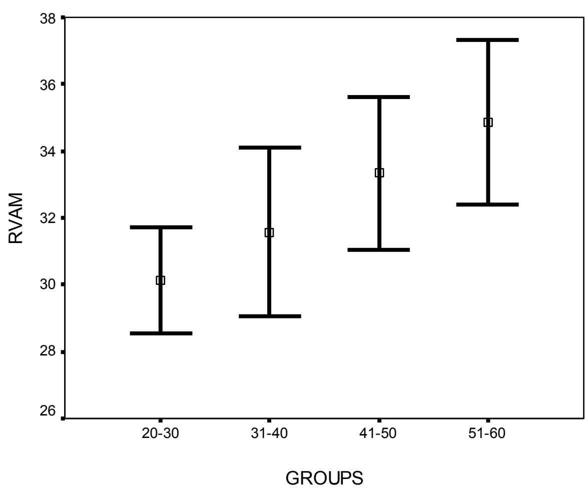


Fig 76: Amplitude Variability of females for age groups between 20-60 years



Syllabic Rate Parameters

1. Average Syllabic Rate (SLrate) (/s)

The results for SLrate are presented in Table 38 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	4.25	2.89	3.12	.54	1.65	2.02	19.59	4.51	17.94	2.50
30-40	3.93	3.79	3.98	3.35	1.78	1.36	30.20	19.62	28.43	18.26
40-50	3.24	4.15	1.28	4.76	1.56	1.46	9.53	30.44	7.97	28.97
50-60	3.74	3.25	2.14	1.63	2.09	1.44	14.68	9.44	12.59	8

The mean SLrate for males in the age group of 20-30 years was found to be 4.25 (SD = 3.12) whereas in females it was 2.89 (SD = .54). The range of SLrate in males was observed as 17.94 and in females it was 2.50. The minimum SLrate in males was 1.65 and in females it was 2.02. The maximum SLrate in males was 19.59 and 4.51 in females. The mean SLrate for males in the age group of 30-40 years was found to be 3.93 (SD = 3.98) whereas in females it was 3.79 (SD = 3.35). The range of SLrate in males was observed as 28.43 and in females it was 18.26. The minimum SLrate in males was 1.78 and in females it was 1.36. The maximum SLrate in males was 30.20 and 19.62 in females. The mean SLrate for males in the age group of 40-50 years was found to be 3.24 (SD = 1.28) whereas in females it was 4.15 (SD = 4.76). The range of SLrate in males was observed as 7.97 and in females it was 28.97. The minimum SLrate in males was 1.56 and in females it was 1.46. The maximum SLrate in males was 9.53 and 30.44 in females. The mean SLrate for males in the age group of 50-60 years was found to be 3.74 (SD = 2.14) whereas in females it was 3.25 (SD = 1.63). The range of SLrate in males was observed as 12.59 and in females it was 8. The minimum SLrate in males was 2.09 and in females it was 1.44. The maximum rSTD in males was 14.68 and 9.44 in females. No significant main effect of age was observed in either females ($F(3,196) = 1.7$, $p < .16$) or males ($F(3,192) = 1.09$, $p < .35$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=11.43, SD=101.04) and males (M=7, SD=29.75) did not reveal significant difference $t(394)=0.59$, $p=.5$

Fig 77: Average Syllabic Rate of males for age groups between 20-60 years

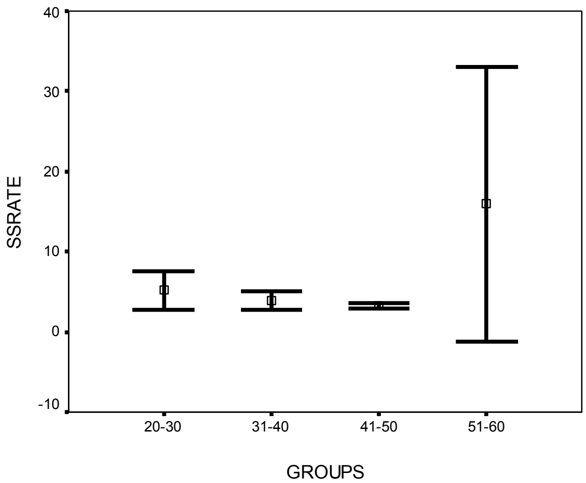
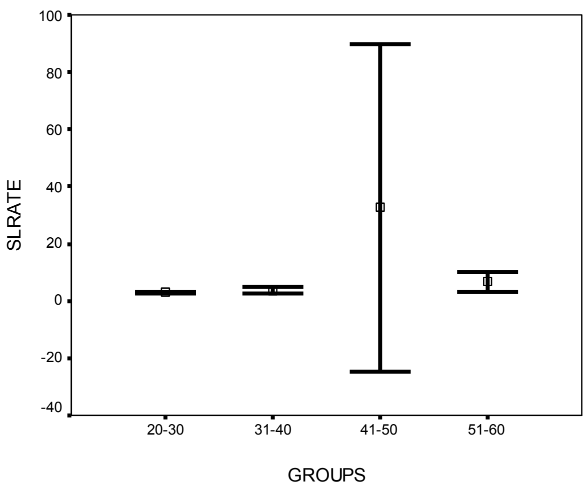


Fig 78: Average Syllabic Rate of females for age groups between 20-60 years



2. Average Syllabic Duration (SLsdur) (ms)

The results for SLsdur are presented in Table 39 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	289.12	320.68	77.34	93.91	129.09	79.84	581.80	474.32	452.71	394.48
30-40	282.32	272.79	85.86	145	27.20	5.27	427.42	735.05	400.22	729.79
40-50	305.79	282.75	81.37	105.60	154.35	66.06	569.15	591	414.80	524.94
50-60	297.69	297.74	89.96	102.11	91.27	115.35	458.27	677.95	367.01	562.61

The mean SLsdur for males in the age group of 20-30 years was found to be 289.12 (SD = 77.34) whereas in females it was 320.68 (SD = 93.91). The range of SLsdur in males was observed as 452.71 and in females it was 394.48. The minimum SLsdur in males was 129.09 and in females it was 79.84. The maximum SLsdur in males was 581.80 and 474.32 in females. The mean SLsdur for males in the age group of 30-40 years was found to be 282.32 (SD = 85.86) whereas in females it was 272.79 (SD = 145). The range of SLsdur in males was observed as 400.22 and in females it was 729.79. The minimum SLsdur in males was 27.20 and in females it was 5.27. The maximum SLsdur in males was 427.42 and 735.05 in females. The mean SLsdur for males in the age group of 40-50 years was found to be 305.79 (SD = 81.37) whereas in females it was 282.75 (SD = 105.60). The range of SLsdur in males was observed as 414.80 and in females it was 524.94. The minimum SLsdur in males was 154.35 and in females it was 66.06. The maximum SLsdur in males was 569.15 and 591 in females. The mean SLsdur for males in the age group of 50-60 years was found to be 297.69 (SD = 89.96) whereas in females it was 297.74 (SD = 102.11). The range of SLsdur in males was observed as 367.01 and in females it was 562.61. The minimum SLsdur in males was 91.27 and in females it was 115.35. The maximum SLsdur in males was 458.27 and 677.95 in females. No significant main effect of age was observed in either females ($F(3,196) = 1.68$, $p < .17$) or males ($F(3,192) = .73$, $p < .5$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=267.78, SD=137.24) and males (M=259.96, SD=119.77) did not reveal significant difference t(394)=0.604, p=.5

Fig 79: Average Syllabic Duration of males for age groups between 20-60 years

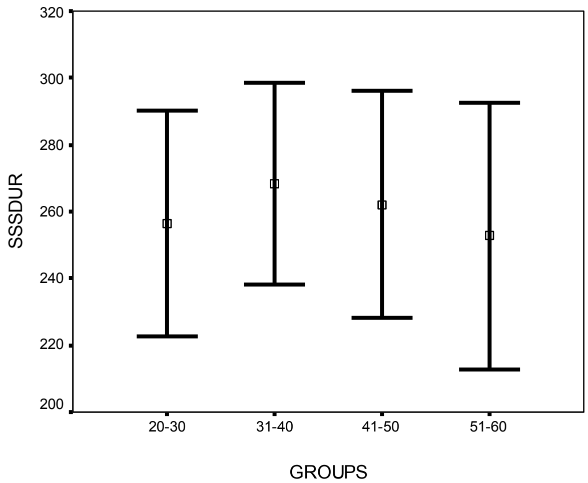
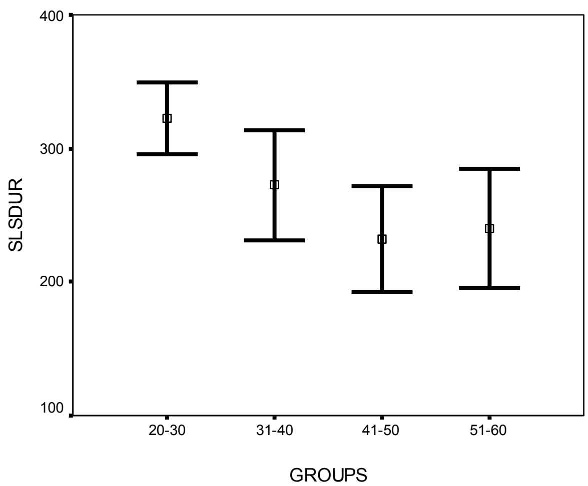


Fig 80: Average Syllabic Duration of females for age groups between 20-60 years



3. Average Pause Duration (SLpdur) (ms)

The results for SLpdur are presented in Table 40 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	177.78	188.02	96.96	71.59	103.02	104.08	474.80	309.97	371.78	205.89
30-40	196.61	199.34	114.95	78.82	103.74	107.29	630.73	398.56	526.99	291.27
40-50	263.21	219.59	199.01	124	106.33	108.51	798.54	653.85	692.20	545.34
50-60	204.13	233.50	137.23	136.72	109.78	106.48	798.54	612.28	688.75	505.80

The mean SLpdur for males in the age group of 20-30 years was found to be 177.78 (SD = 96.96) whereas in females it was 188.02 (SD = 71.59). The range of SLpdur in males was observed as 371.78 and in females it was 205.89. The minimum SLpdur in males was 103.02 and in females it was 104.08. The maximum SLpdur in males was 474.80 and 309.97 in females. The mean SLpdur for males in the age group of 30-40 years was found to be 196.61 (SD = 114.95) whereas in females it was 199.34 (SD = 78.82). The range of SLpdur in males was observed as 526.99 and in females it was 291.27. The minimum SLpdur in males was 103.74 and in females it was 107.29. The maximum SLpdur in males was 630.73 and 398.56 in females. The mean SLpdur for males in the age group of 40-50 years was found to be 263.21 (SD = 199.01) whereas in females it was 219.59 (SD = 124). The range of SLpdur in males was observed as 692.20 and in females it was 545.34. The minimum SLpdur in males was 106.33 and in females it was 108.51. The maximum SLpdur in males was 798.54 and 653.85 in females. The mean SLpdur for males in the age group of 50-60 years was found to be 204.13 (SD = 137.23) whereas in females it was 233.50 (SD = 136.72). The range of SLpdur in males was observed as 688.75 and in females it was 505.80. The minimum SLpdur in males was 109.78 and in females it was 106.48. The maximum SLpdur in males was 798.54 and 612.28 in females. No significant main effect of age was observed in either females ($F(3,137) = .96$, $p < .4$) or males ($F(3,132) = .89$, $p < .4$) as revealed by the results of One-way ANOVA. The independent t-test between the females (M=275, SD=338.83) and males (M=222.93, SD=167.71) did not reveal significant difference t(275)=1.61, p=.1

Fig 81: Average Pause Duration of males for age groups between 20-60 years

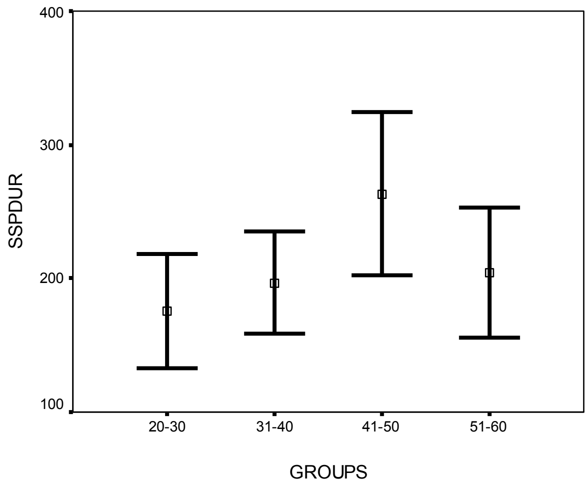
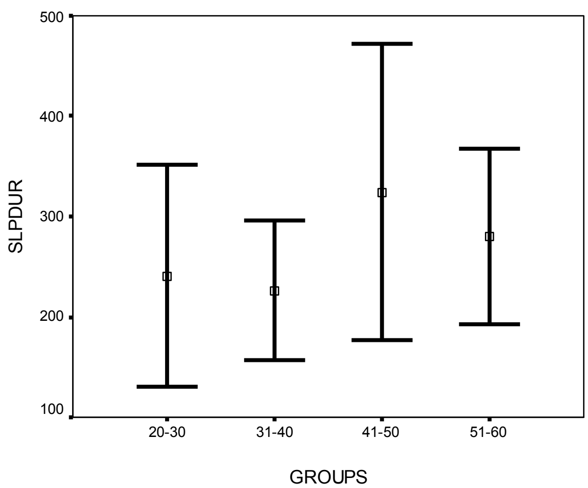


Fig 82: Average Pause Duration of females for age groups between 20-60 years



4. Percent Speaking Time (SLspk) (%)

The results for SLspk are presented in Table 41 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	86.36	89.68	23.80	20.80	14.98	23.67	100	100	85.02	76.33
30-40	82.69	79.85	21.77	23.40	7.98	6.33	100	100	92.02	93.67
40-50	75.12	69.38	26.25	27.97	13.04	4.50	100	100	86.97	95.50
50-60	87.21	70.95	17.69	28.77	22.27	7.46	100	100	77.73	92.54

The mean SLspk for males in the age group of 20-30 years was found to be 86.36 (SD = 23.80) whereas in females it was 89.68 (SD = 20.80). The range of SLspk in males was observed as 85.02 and in females it was 76.33. The minimum SLspk in males was 14.98 and in females it was 23.67. The maximum SLspk in males was 100 and 100 in females. The mean SLspk for males in the age group of 30-40 years was found to be 82.69 (SD = 21.77) whereas in females it was 79.85 (SD = 23.40). The range of SLspk in males was observed as 92.02 and in females it was 93.67. The minimum SLspk in males was 7.98 and in females it was 6.33. The maximum SLspk in males was 100 and 100 in females. The mean SLspk for males in the age group of 40-50 years was found to be 75.12 (SD = 26.25) whereas in females it was 69.38 (SD = 27.97). The range of SLspk in males was observed as 86.97 and in females it was 95.50. The minimum SLspk in males was 13.04 and in females it was 4.50. The maximum SLspk in males was 100 and 100 in females. The mean SLspk for males in the age group of 50-60 years was found to be 87.21 (SD = 17.69) whereas in females it was 70.95 (SD = 28.77). The range of SLspk in males was observed as 77.73 and in females it was 92.54. The minimum SLspk in males was 22.27 and in females it was 7.46. The maximum SLspk in males was 100 and 100 in females. There was a significant age effect in both females [F(3,136)= 6.8, p=.00] and males [F(3,191)=2.8, p=.03] as revealed by the results of One-way ANOVA. The independent t-test between the females (M=77.47, SD=26.53) and males (M=81.24, SD=25.38) did not reveal significant difference t(394)= -1.44, *p*=.1

Fig 83: Percent Speaking Time of males for age groups between 20-60 years

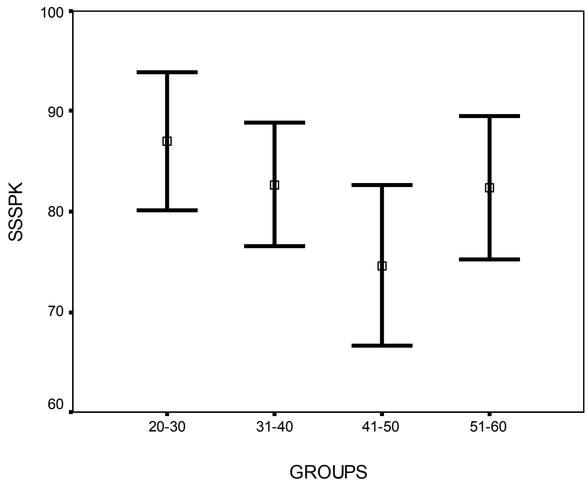
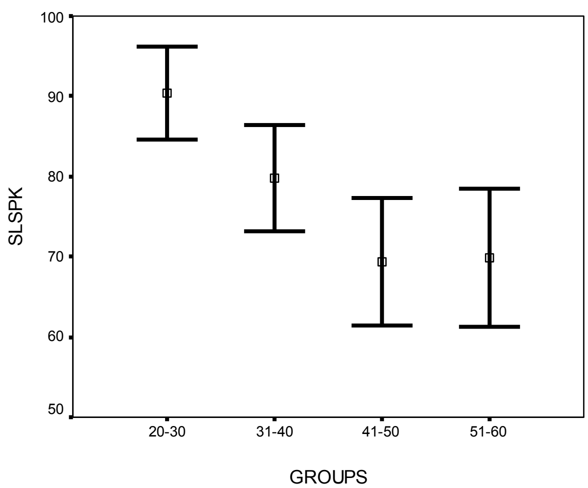


Fig 84: Percent Speaking Time of females for age groups between 20-60 years



5. Percent Pause Time (SLpau) (%)

The results for SLpau are presented in Table 42 below

Age range (years)	Mean		S.D		Minimum		Maximum		Range	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
20-30	31.51	30.33	31.30	26.07	3.68	3.20	99.78	76.33	96.10	73.14
30-40	20.67	27.22	17.15	23.40	3.44	6.33	75.12	93.67	71.68	87.35
40-50	28.65	35.15	28.01	27.61	4.70	3.29	95.10	95.50	90.40	92.21
50-60	14.74	31.49	20.73	27.03	3.06	2.70	77.73	92.54	74.66	89.84

The mean SLpau for males in the age group of 20-30 years was found to be 31.51 (SD = 31.30) whereas in females it was 30.33 (SD = 26.07). The range of SLpau in males was observed as 96.10 and in females it was 73.14. The minimum SLpau in males was 3.68 and in females it was 3.20. The maximum SLpau in males was 99.78 and 76.33 in females. The mean SLpau for males in the age group of 30-40 years was found to be 20.67 (SD = 17.15) whereas in females it was 27.22 (SD = 23.40). The range of SLpau in males was observed as 71.68 and in females it was 87.35. The minimum SLpau in males was 3.44 and in females it was 6.33. The maximum SLpau in males was 75.12 and 93.67 in females. The mean SLpau for males in the age group of 40-50 years was found to be 28.65 (SD = 28.01) whereas in females it was 35.15 (SD = 27.61). The range of SLpau in males was observed as 90.40 and in females it was 92.21. The minimum SLpau in males was 4.70 and in females it was 3.29. The maximum SLpau in males was 95.10 and 95.50 in females. The mean SLpau for males in the age group of 50-60 years was found to be 14.74 (SD = 20.73) whereas in females it was 31.49 (SD = 27.03). The range of SLpau in males was observed as 74.66 and in females it was 89.84. The minimum SLpau in males was 3.06 and in females it was 2.70. The maximum SLpau in males was 77.73 and 92.54 in females. The results of One-way ANOVA pointed towards no significant difference in mean across the different age groups in females ($F(3,137) = .62$, $p < .6$) while significant difference was observed in males ($F(3,132) = 3.03$, $p < .03$). The independent t-test between the females (M=32.07, SD=26.53) and males (M=26.95, SD=26.61) did not reveal significant difference $t(275)=1.6$, $p=0.1$.

Fig 85: Percent Pause Time of males for age groups between 20-60 years

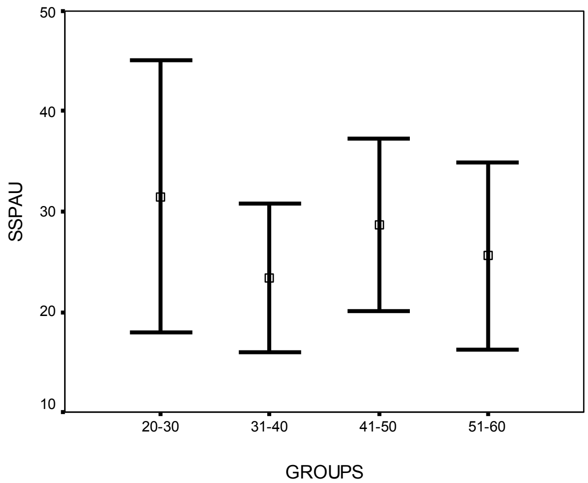
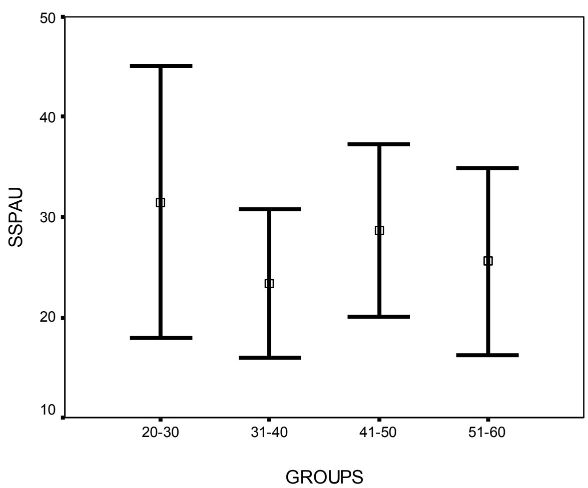


Fig 86: Percent Pause Time of females for age groups between 20-60 years



DISCUSSION

The current study was designed to obtain normative database for the Motor Speech Profile in 4 different age groups between 20-60 years independently for males and females. The parameters that are related to domain of speech production were extracted using the MSP. The speech parameters largely included diadochokinetic rate, second formant transition, voice, tremors, intonation, and syllabic rate. All these parameters are variably affected in persons with motor speech disorders. The current study envisioned to delineate impact of age and gender on various speech parameters. The results for Average DDK Period (DDK avp) suggest no differences between the different age groups in either males or females and no impact of gender as reflected by no statistically significant differences between males and females. Similar to DDK avp, the Average DDK rate (DDK avr) too did not differ significantly with respect to age and gender. The Standard Deviation of DDK Period (DDKsdp) demonstrated significant variability in males with reference to different age groups while no significant difference was observed in females. The mean DDKsdp was higher in lower age groups compared to higher age groups in males. Overall, no significant difference was observed between males and females for DDKsdp. The results for The Coefficient of Variation of DDK Period (DDK cvp) were similar to DDK sdp. The Perturbation of DDK Period (DDK jit) showed no significant effect of age in females where as significant difference was found in males. While there was no significant difference in mean DDKjit between males and females. For Average DDK Peak Intensity (DDK avi) and Standard Deviation of DDK Peak Intensity (DDK sdi), age effect was significant in females and not in males. The gender effect was observed for both these parameters. The Coefficient of Variation of DDK Peak Intensity (DDK cvi) showed significant difference in mean between different age groups in females while no such effect was seen in males. No gender effect was observed for DDKsdi. The results were contrasting for Maximum Intensity of DDK Sample (DDK mxa) and Average Intensity of DDK Sample (DDK ava) specifically demonstrating significant main effect of age for age for DDKava and no such effect for DDKmxa. Gender impact was observed for DDKmxa and no impact for DDKava. For Average Syllabic Intensity (DDK sla), the results pointed towards significant difference in mean across the different age groups in females while no significant difference was observed in males. The gender variable demonstrated no significant difference.

The 3 second formant transition measurements including Magnitude of F2 variation (F2magn), Average of F2 Value (F2aver), and Maximum F2 Value (F2max) presented significant age effect in both males and females while no impact of gender was observed. The results for Rate of F2 Variation (F2rate), Regularity of F2 Variation (F2reg), and Minimum F2 Value (F2min) were different from 3 aforementioned parameters. In case of F2rate, F2reg, and F2min no significant main effect of age was observed in either females or males. However, significant difference was found between males and females.

For voice measurements involving Average Fundamental Frequency (F0), Average Pitch Period (To), Highest Fundamental Frequency (Fhi), Standard Deviation of F0 (STD), and Coefficient of Variation of F0 (vFo) suggested significant difference in mean across the different age groups in females but not in males. The impact of gender was found for F0, Fhi, and STD but not for T0 and vF0. While no significant age effect was observed in either females or females for Lowest Fundamental Frequency (Flo), the impact was obvious for Coefficient of Variation of Amplitude (vAm). But gender impact was seen for both parameters.

Concerning tremor measurements, the Magnitude Frequency Tremor (Mftr) demonstrated significant difference in mean across the different age groups in females while no significant difference was observed in males. The gender impact was not found for Mftr. For Magnitude Amplitude Tremor (Matr), significant age effect was observed in both females and males but no impact of gender was observed for this measurement. In contrast, no significant difference was seen with respect to age for tremor parameters including Rate of Frequency Tremor (Rftr), Rate of Amplitude Tremor (Ratr), Periodicity of Frequency Tremor (Pftr), and Periodicity of Amplitude Tremor (Patr). The gender effect was found for Ratr but no such effect was demonstrated for Rftr, Pftr, and Patr.

The results for Intonation Stimulability module suggested significant difference in mean across the different age groups in females but not in males for parameters involving

Running Speech Fundamental Frequency (rFo), Running Speech Pitch Period (rTo), Lowest Fundamental Frequency (rFlo), and Amplitude Variability (rvAm). While impact of gender was found in rFo, rTo, and rFlo, no difference was observed for rvAm. The age related findings were found to be alternative or contrastive for parameters of Highest Fundamental Frequency (rFhi), Standard Deviation of Fundamental Frequency (rSTD), and Frequency Variability (rvFo) specifically results suggested significant differences in males compared to non-significant differences in females. The gender impact was constant for these 3 parameters.

The Syllabic Rate Parameters presented no significant main effect of age in either females or males for Average Syllabic Rate (SLrate), Average Syllabic Duration (SLsdur), Average Pause Duration (SLpdur). Similarly, gender effect was also absent for these parameters. In contrast, for Percent Speaking Time (SLspk), there was significant age effect in both females and males. But no significant difference was observed between gender for SLspk. For Percent Pause Time (SLpau), no significant difference in mean across the different age groups was found in females while significant difference was observed in males. The gender as variable had no impact for SLpau.

The overall results revealed variability concerning impact of age and gender for various MSP acoustic parameters. The previous similar study by Deliyski and Gress (1997) that obtained normative data in healthy male and female subjects (age range: 18-60 years) using the Motor Speech Profile (MSP) Model 4341 yielded gender based differences for measures of F0 and second formant characteristics. Similar differences were observed in the current study that can be attributed to typical male/female structural features of the larynx and the vocal tract. Where as the Padovani et al., (2009) study that examined DDK rate in healthy adults suggested that DDK rate did not vary with age with the exception for peak intensity that demonstrated variation in the elderly subjects. The results of the current will have to be weighed against the findings in neuromotor speech disorders including different dysarthria varieties, apraxia of speech, among others.

SUMMARY AND CONCLUSIONS

The current project aimed at developing the normative database of the Motor Speech Profile for individuals between 20-60 years. 400 healthy participants comprising equal number of males and females formed the subject group. The database was obtained separately for 4 different age groups in both males and females. The preliminary speech, voice, and hearing assessments were carried out to rule out any communication problems. The data was obtained by strictly adhering to the protocol prescribed in the Motor Speech Profile. The 5 parameters studied were diadochokenetic rate, voice and tremor, second formant transition, intonation stimulability protocol, and standard syllabic rate. Each of these parameters consisted several subparameters. The MSP automatically numerically report the results of all parameters following the completion of recording protocol.

The salient conclusions that can be drawn from the results are:

1) Diadochokenetic Rate:-

- The mean Average DDK Period **(**DDK avp) was highest in 30-40 years age group in males while it was highest in 40-50 years age in females. Overall it was highest in females than males. However, no significant effect of either age or gender was observed concerning DDK avp.
- The mean Average DDK Rate (DDK avr) was highest in 40-50 years age group in males while it was highest in 20-30 years age group in females. The mean DDK avr was higher for males compared to females. No significant impact of either age or gender with respect to DDK avr.

- The mean Standard Deviation of DDK Period (DDK sdp) was highest for 20-30 years age group in males and 40-50 years age group in females. The mean DDK sdp was higher in females compared to males. Age effect was seen in both males and females while gender effect was not observed with respect to DDK sdp.
- The mean Coefficient of Variation of DDK Period (DDK cvp) was highest in 30-40 years age group in males and it was highest in 40-50 years age group in females. The DDK cvp was higher in females compared to males. Age effect was seen in both females and males while no significant influence of gender was observed for DDK cvp.
- The mean Perturbation of DDK Period (DDK jit) was highest for 20-30 years age group in males while it was highest for 40-50 years age group in females. The DDK jit was higher in females than males. The age effect was not seen in females while it was observed in males. No influence of gender was observed for DDK jit.
- The mean DDK peak intensity (DDK avi) was highest in 20-30 years age group in both males and females. It was higher in females compared to males. Age effect was observed in females while no such effect was found in males. Significant influence of gender was observed.
- The mean Standard Deviation of DDK Peak Intensity (DDK sdi) was highest in 30-40 years age group in males where as it was highest in 50-60 years age group in females. The DDK sdi was higher for males than females. Age effect was observed for females while no such effect was found in males. Gender effect was observed for DDK sdi.

- The mean Coefficient of Variation of DDK Peak Intensity (DDK cvi) was highest in 30-40 years age group in males while it was highest for 50-60 years age group in females. The mean DDK cvi was higher in males compared to females. Age effect was observed for females while no such effect was found in males. Significant gender effect was not observed for DDK sdi.
- The mean Maximum Intensity of DDK Sample (DDK mxa) was highest in 30-40 years age group in males while it was highest in 50-60 years age group in females. The DDK mxa was higher in males than females. No significant age effect was observed in either males or females while gender effect was found for DDK mxa.
- The mean Average Intensity of DDK Sample (DDK ava) was highest in 20-30 years age group in both males and females. However, it was higher in males compared to females. Age effect was observed in both males and females while no significant gender effect was found for DDK ava.
- The mean Average Syllabic Intensity (DDK sla) was highest in 20-30 years age group in both males and females. However, it was higher in males compared to females. Significant age effect was found in females while no significant effect was found in males. Gender effect was not seen for DDK sla.

2) Second Formant Transition :-

- The mean Magnitude of F2 variation (F2 magn) was highest in 40-50 years age group in males while it was highest in 50-60 years age group in females. It was higher in females compared to males. Significant age effect was found in both males and females while no significant effect of gender was found for F2 magn.

- The mean Rate of F2 Variation (F2 rate) was highest in 20-30 years age group in males where as it was highest in 50-60 years age group in females. The mean F2 rate was higher in females compared to males. No significant age effect was seen in both males and females while gender effect eas observed for F2 rate.

- The mean Regularity of F2 Variation (F2 reg) was highest in 50-60 years age group in males where as it was highest in 40-50 years age group in females. The mean F2 reg was higher in males than females. No significant age effect was found in both males and females while gender effect was found for F2 reg.

- The Average of F2 Value (F2aver) was highest for 20-30 years age group in males where as it was highest for 40-50 years age group in females. The mean F2 aver was higher for females than males. Significant age effect was seen in both males and females while so significant difference was observed between males and females.

- The mean Minimum F2 Value (F2 min) was highest for 20-30 years age group in males whereas it was highest for 30-40 years age group in females. The F2 min was higher in males compared to females. No significant main effect of age was found in females while significant age effect was seen in males. Gender effect was significant for F2 min.

- The mean Maximum F2 Value (F2 max) was highest for 40-50 years age group in both males and females. The mean F2 max was higher in females than males. But no significant gender effect was observed. Age effect was also significant in both males and females.

3) Voice Parameters

- The Average Fundamental Frequency (F0) was highest for 30-40 years age group in both males and females. The mean F0 was higher in females than males. Significant age effect was found in females and not in males. Gender effect was significant for F0.

- The Average Pitch Period (To) was highest in 40-50 years age group in males while it was highest in 50-60 years age group in females. The mean To was higher in males than females but not suggesting significant effect of gender. The age effect was significant in females but not in males.

- The mean Highest Fundamental Frequency (Fhi) was highest in 20-30 years age group in males while it was highest in 40-50 years age group in females. The mean Fhi was higher in females than males suggesting significant gender effect. Age effect was significant in females and not in males.

- The mean Lowest Fundamental Frequency (Flo) was lowest in 40-50 years age group in both males and females. It was lowest in males compared to females suggesting significant effect of gender. No main effect of age was found in both males and females.

- The mean Standard Deviation of F0 (STD) was highest in 40-50 years age group in both groups of participants. It was higher in females than males suggesting significant gender effect. Age effect was significant in females but not in males.

- The mean Coefficient of Variation of F0 (vFo) was highest in 20-30 years age group in males and 40-50 years age group in females. The vFo was higher in males than females but the difference was not significant. Age effect was significant in females but not in males.

- The mean Coefficient of Variation of Amplitude (vAm) was highest in 40-50 years age group in both groups of participants. Age and gender effect was significant for vAm.

4) Tremor Parameters

- The mean Magnitude Frequency Tremor (Mftr) was highest in 50-60 years age group in males while it was highest in 40-50 years age group in females. Age effect was seen in females while no significant effect was found in males. Gender effect was not observed for Mftr.

- The mean Magnitude Amplitude Tremor (Matr) was highest in 30-40 years age group in males while it was highest in 40-50 years age group in females. Age main effect was found in both groups of participants while no gender effect was observed.

- The mean Rate of Frequency Tremor (Rftr) was highest in 50-60 years group in males while it was highest in 40-50 years group. No gender effect was found for Rftr and no age effect was found.

- The mean Rate of Amplitude Tremor (Ratr) was highest in 20-30 years group in males whereas it was highest in 30-40 years group in females. Age effect was not seen in either males or females. Gender effect was prominent for Ratr.
- The mean Periodicity of Frequency Tremor (Pftr) was highest in 20-30 years group in males while it was highest in 40-50 years group in females. No significant age or gender effect was observed for Pftr.
- The mean Periodicity of Amplitude Tremor (Patr) was highest in 30-40 years age group in males while it was highest in 50-60 years age group in females. No significant age or gender effect was observed for Patr.

5) Intonation Stimulability Parameters

- The mean Running Speech Fundamental Frequency (rFo) was highest in 50-60 years age group in males while it was highest for 20-30 years age group in females. The age effect was found in females while no significant age effect was observed in males. Gender effect was found to be significant.
- The mean Running Speech Pitch Period (rTo) was highest in 20-30 years group in males whereas it was highest in 40-50 years group in females. The rTo was higher in males than females suggesting significant effect of gender. Age effect was prominent in females while it was not significant in males.
- The mean Highest Fundamental Frequency (rFhi) was highest in 40-50 years age groups in both groups of participants. The gender effect was significant for rFhi. Age effect was not significant in females but significant in males.

- The mean Lowest Fundamental Frequency (rFlo) was lowest for 30-40 years age group in males while it was lowest for 40-50 years age group in females. Age effect was significant in females while it was not significant in males. The gender effect was prominent for rFlo.

- The mean Standard Deviation of Fundamental Frequency (rSTD) was highest in 40-50 years age group in both males and females. Age effect was significant in males but not in females. Gender effect was significant for rSTD

- The mean Frequency Variability (rvFo) was highest in 40-50 years age group in both groups of participants. Age effect was not seen in females but found in males. Gender effect was significant for rvFo.

- The mean Amplitude Variability (rvAm) was highest in 40-50 years age group in males while it was highest in 50-60 years age group in females. Age effect was significant in females but not in males. The gender effect was not found for rvAm.

6) Syllabic Rate Parameters

- The Average Syllabic Rate (SLrate) was highest in 20-30 years age group in males and in 40-50 years age group in females. No significant main effect of age or gender was observed for SLrate.

- The Average Syllabic Duration (SLsdur) was highest in 40-50 years age group in males and 20-30 years group in females. No significant main effect of age or gender was observed for SLsdur.

- The Average Pause Duration (SLpdur) was highest in 40-50 years group in males and 50-60 years group in females. No significant main effect of age or gender was observed for SLpdur.

- The mean Percent Speaking Time (SLspk) was highest in 50-60 years group in males and 20-30 years group in females. Age main effect was significant in both groups of participants but no significant gender influence was observed.

- The Percent Pause Time (SLpau) was highest in 20-30 years group in males and 40-50 years group in females. Age effect was significant in males but not in females. No significant effect for gender was found for SLpau.

Implications:

The study has several implications –

1) The results form important data base for several aspects of speech production in Indian population.
2) Any person's speech resulting due to abnormal neuromotor planning and execution can be differentially distinguished from normal speech.
3) The results demonstrate impact of age and gender for several speech features.

REFERENCES

Ackermann, H., & Ziegler, W. (1991). Cerebellar voice tremor: an acoustic analysis. *Journal of Neurology, Neurosurgery, and Psychiatry, 54,* 74–76.

Baum, S. R., Blumstein, S. E., Naeser, M. A., & Palumbo, C.L. (1990). Temporal dimensions of consonant and vowel production: An acoustic and CT scan analysis of aphasic speech. *Brain and Language, 39,* 33-56.

Brodal, P. (1998). *The central nervous system: Structure and function* (2nd ed.) New York, NY: Oxford University Press.

Canter, G. (1963). Speech characteristics of patients with Parkinson's disease: I. Intensity, pitch, and duration. *Journal of Speech and Hearing Disorders, 28,* 221–229.

Canter, G. (1965). Speech characteristics of patients with Parkinson's disease: II. Physiological support for speech. *Journal of Speech and Hearing Disorders, 30,* 44–49.

Collins, M. (1984). Integrating perceptual and instrumental procedures in dysarthria assessment. *Journal of Communication Disorders, 5,* 159–170.

Countryman, S., & Ramig, L. (1993). Effects of intensive voice therapy on voice deficits associated with bilateral thalamotomy in Parkinson disease: A case study. *Journal of Medical Speech- Language Pathology, 4,* 233–250.

D'Alatri, L., Paludetti, G., Contarino, M. F., Galla, S., Marchese, M. R., & Bentivoglio, A. R. (2008). Effects of bilateral subthalamic nucleus stimulation and medication on Parkinsonian speech impairment. *Journal of Voice, 22(3),* 365–372.

Darkins, A., Fromkin V., & Benson, D., (1988). A characterization of the prosodic loss in Parkinson's disease. *Brain and Language, 34,* 315–327.

Darley, F.L., Aronson, A.E., & Brown, J.R. (1975). Motor Speech Disorders. Philadelphia: W.B. Saunders.

Darley, F., Aronson, A., & Brown, J. (1969). Differential diagnosis patterns of dysarthria. *Journal of Speech and Hearing Research, 12,* 246–269.

Deliyski, D. D., & Gress, C. D. (1997). *Characteristics of Motor Speech Performance: Normative Data.* Presented at ASHA'97, Boston, Massachusetts.

Doyle, P., Raade, A., St. Pierre A., & Desai, S., (1995). Fundamental frequency and acoustic variability associated with production of sustained vowels by speakers with hypokinetic dysarthria. *Journal of Medical Speech-Language Pathology, 3,* 41–50.

Duffy, J. R. (2005). *Motor speech disorders: Substrates, differential diagnosis, and management* (2nd ed.). St. Louis, MO: Elsevier Mosby.

Enderby, P. & Palmer, R. (2008). *Frenchay Dysarthria Assessment,* 2nd Edition, Philedelphia:Pro-ed.

Fletcher, S. (1972). Time-by-count measurement of diadochokinetic syllable rate. *Journal of Speech and Hearing Research, 15,* 757–762.

Harmes, S., Daniloff, R., Hoffman, P., Lewis, J., Kramer, M., & Absher, R. (1984). Temporal and articulatory control of fricative articulation by speakers with Broca's aphasia. *Journal of Phonetics, 12,* 367-385.

Hertrich, I., & Ackermann, H. (1995). Gender-specific vocal dysfunctions in Parkinson's Disease: Electroglottographic and acoustic analyses. *Annals of Otology, Rhinology, and Laryngology, 104,* 197–202.

Ho, A., Iansek, R., & Bradshaw, J., (2001). Motor instability in parkinsonian speech intensity. *Neuropsychiatry Neuropsychol Behav Neurol, 14,* 109–116.

Ho, A., Bradshaw, J., Iansek, R., & Alfredson, R., (1999). Speech volume regulation in Parkinson's disease: effects of implicit cues and explicit instructions. *Neuropsychologia, 37,* 1453–1460.

Holmes, R., Oates, J., Phyland, D., & Hughes, A. (2000). Voice characteristics in the progression of Parkinson's disease. *International Journal of Language and Communication Disorders, 35,* 417–418.

Jimenez-Jimenez, F., Gamboa, J., Nieto, A., Guerrero, J., Orti-Pareja, M., Molina, J., Garcia-Albea E., & Cobeta, I. (1997). Acoustic voice analysis in untreated patients with Parkinson's disease. *Parkinsonism and Related Disorders, 3,* 111–116.

Kent, R. D., & Rosenbeck, J. C. (1983). Acoustic patterns of apraxia of speech. *Journal of Speech and Hearing Research, 26,* 231-249.

Kent, R. D., & McNeil, M. R. (1987). *Relative timing of sentence repetition in apraxia of speech and conduction aphasia.* In J. H. Ryalls (Ed.), *Phonetic approaches to speech production in aphasia and related disorders,* (pp. 181-220). San Diego: College Hill Press.

Kent, R., Kim, H., Weismer, G., Kent, J., Rosenbek, J., Brooks B., & Workinger, M. (1994). Laryngeal dysfunction in neurological disease: Amyotrophic lateral sclerosis, Parkinson disease, and stroke. *Journal of Medical Speech-Language Pathology, 2,* 157–175.

Kent, R. D., Kent, J. F., Rosenbek, J. C., Vorperian, H. K., & Weismer, G. (1997). A speaking task analysis of the dysarthria in cerebellar disease. *Folia Phoniatrica et Logopaedica, 49,* 63 82.

Kent, R. D., Weismer, G., Kent, J. F., Vorperian, H. K., & Duffy, J. R. (1999). Acoustic Studies of Dysarthric Speech: Methods, Progress, and Potential. *Journal of Communication Disorders. 32,* 141-86.

King, J., Ramig, L., Lemke, J., & Horii, Y., (1994). Parkinson's disease: Longitudinal changes in acoustic parameters of phonation. *Journal of Medical Speech-Language Pathology, 2,* 29– 42.

Le Dorze, G., Ouellet, L., & Ryalls, J., (1994). Intonation and speech rate in dysarthric speech. *Journal of Communication Disorders, 27,* 1–17.

Le Dorze, G., Ryalls, J., Brassard, C., Boulanger N., & Ratte, D. (1998). A comparison of the prosodic characteristics of the speech of people with Parkinson's disease and Friedrich's ataxia with neurologically normal speakers. *Folia Phoniatrica et Logopaedica, 50,* 1-9.

Linville, S. E. (2000). *"The aging voice," in Voice Quality Measurement,* R. D. Kent and M. J. Ball, Eds., pp. 359–376. Singular Thomson Learning, San Diego, CA.

Ludlow, C. & Bassich, C. (1983). *The results of acoustic and perceptual assessment of two types of dysarthria:* Clinical Dysarthria, W. Berry, ed., College-Hill Press, San Diego, pp. 121–153.

Ludlow, C., Connor, N., & Bassich, C., (1987). Speech timing in Parkinson's and Huntington's Disease. *Brain and Language, 32,* 195–214.

Lundy, D.S., Roy, S., Xue, J.W., Casiano, R.R., & Jassir, D. (2004).

Spastic/spasmodic Vs tremulous vocal quality: Motor speech profile analysis. *Journal of Voice, 18,* 146-152.

McNeil, M. R., Liss, J.M., Tseng, C. H., & Kent, R. D. (1990). Effects of speech rate on the absolute and relative timing of apraxic and conduction aphasic sentence production. *Brain and Language, 38,* 135-158.

Metter, J., & Hanson, W. (1986). Clinical and acoustical variability in hypokinetic dysarthria*. Journal of Communication Disorders, 19,* 347–366.

Murdoch, B. E., Chenery, H. J., Stokes, P. D., & Hardcastle, W. J. (1991). Respiratory kinematics in speakers with cerebellar disease. *Journal of Speech and Hearing Research, 34(4),*768-80.

Ozsancak, C., Auzou, P., Jan, M., & Hannequin, D. (2001). Measurement of voice onset time in dysarthric patients: Methodological considerations. *Folia Phoniatrica et Logopaedica 53(1),* 48-57.

Padovani, M., Gielow, I., & Behlau, M. (2009). Phonarticulatory diadochokinesis in young and elderly individuals. *Arq Neuropsiquiatr, 67(1),* 58-61.

Penner, H., Miller., & Wolters, M. (2007). Motor speech disorders in three Parkinsonian syndromes: A comparative study. In *Proc. Intl. Conf. Phon. Sci.*

Ramig, L. A. (1986). Acoustic analyses of phonation in patients with Huntington's disease. Preliminary report. *Annals of Oto-RhinoLaryngology, 95,* 288-293.

Ramig, L., Sapir, S., Fox, C. & Countryman, S. (2001). Changes in vocal loudness following intensive voice treatment (LSVT) in individuals with Parkinson's disease: a comparison with untreated patients and normal age-matched controls. *Movement Disorders, 16,* 79–83.

Robb, M., Blomgren, M., & Chen, Y. (1998). Formant frequency fluctuation in stuttering and non-stuttering adults. *Journal of Fluency Disorders, 23,* 73–84.

Schalling, E., & Hartelius, L. (2004). Acoustic analysis of speech tasks performed by three individuals with spinocerebellar ataxia. *Folia Phoniatrica et Logopaedica 56(6),* 367-80.

Strand, E. A., Buder, E. H., Yorkston, K. M., & Ramig, L. O. (1994). Differential phonatory characteristics of four women with amyotrophic lateral sclerosis. *Journal of Voice, 8(4),* 327-339.

Vasanta, D. (1990). Maximizing phonological information from picture word articulation test. In S.V. Kacker & V. Basavaraj (Eds). *The ISHA test battery.* Indian Speech and Hearing Association.

Walton, J. H., & Orlikoff, R. F. (1994). Speaker race identification from acoustic cues in the vocal signal. *Journal of Speech and Hearing Research, 37(4),* 738-745.

Wang, Y. T., Kent, R. D., Duffy, J. R., Thomas, J. E., & Weismer, G. (2004). Alternating motion rate as an index of speech motor disorder in traumatic brain injury. *Clinical Linguistics & Phonetics, 18,* 57–84.

Wang, Y. T., Kent, R. D., Duffy, J. R., & Thomas, J. E. (2005). Dysarthria associated with traumatic brain injury: speaking rate and emphatic stress. *Journal of Communication Disorders, 38(3),* 231-260.

Wang, Y. T., Kent, R. D., Duffy, J. R., & Thomas, J. E. (2008). Analysis of diadochokinesis in ataxic dysarthria using the motor speech profile program^{TM}. *Folia Phoniatrica et Logopaedica, 61(1), 1–11.*

Watanabe, S., Arasaki, K., Nagata, H., & Shouji, S. (1994). Analysis of dysarthria in amyotrophic lateral sclerosis--MRI of the tongue and formant analysis of vowels. *Rinsho Shinkeigaku. 34(3),* 217-23.

Weismer, G. (1984) *Articulatory characteristics of Parkinsonian dysarthria: segmental and phrase-level timing, spirantization, and glottal-supraglottal coordination. The Dysarthrias: Physiology, Acoustics, Perception, Management,* M. McNeil, J. Rosenbeck and A. Aronson, eds, College-Hill Press, San Diego,101–130.

Wong, A. W., Allegro, J., Tirado, Y., Chadha, N., & Campisi, P. (2011). Objective measurement of motor speech characteristics in the healthy pediatric population. *International Journal of Pediatric Otorhinolaryngology, 160,* 4-11.

Wood, S., Wishart, J, Hardcastle, W.J., Cleland, J. and Timmins , C. (2009) The use of electropalatography (EPG) in the assessment and treatment of motor speech disorders in children with Down's syndrome: Evidence from two case studies. *Developmental Neurorehabilitation*, *12(2),* 66-75.

Yorkston, K., & Beukelman, D. R. (1981). Ataxic dysarthria: Treatment sequences based on intelligibility and prosodic considerations. *Journal of Speech and Hearing Disorders, 46,* 398-404.

Ziegler, W. & von Cramon, D. (1983). Vowel distortion in traumatic dysarthria: Lip rounding versus tongue advancement. *Phonetica, 40,*312-322.

Ziegler, W. & von Cramon, D. (1986). Spastic dysarthria after acquired brain injury: An acoustic study. *British Journal of Disorders of Communication, 21,*173-187.

Zwirner, P., & Barnes, G. (1992). Vocal tract steadiness: A measure of phonatory stability and upper airway motor control during phonation in dysarthria. *Journal of Speech and Hearing Research, 35,* 761–768.

APPENDIX 1

Results across gender in different age groups

a) Acoustic variables across gender for age group 20-30 years

Parameters	Gender							
	Male				Female			
	Mean	SD	Min	Max	Mean	SD	Min	Max
DDK Parameters								
DDKavp, ms	214.31	75.34	123.57	443.00	238.35	160.43	111.54	940.76
DDKavr, /s	4.68	1.80	.56	7.49	5.23	1.93	1.06	8.97
DDKsdp, ms	125.76	70.43	10.22	351.43	230.04	90.74	93.74	395.56
DDKcvp, %	49.65	25.80	4.04	90.85	67.24	25.98	6.68	128.28
DDKjit, %	19.96	22.07	1.07	100.02	17.36	16.09	1.30	72.74
DDKavi, dB	66.24	5.79	54.35	78.96	66.62	4.81	56.79	76.11
DDKsdi, dB	3.71	1.90	.64	7.85	3.24	1.62	.52	9.18
DDKcvi, %	5.52	2.60	1.14	10.38	4.83	2.25	.68	12.72
DDKmxa, dB	72.77	7.47	54.97	88.93	72.22	5.78	57.31	87.46
DDKava, dB	59.02	7.67	44.23	69.57	61.58	5.71	44.92	67.48
DDKsla, dB	63.43	3.77	54.16	69.70	64.71	3.95	56.57	75.95
F2 Transition Parameters								
F2magn, Hz	133.99	32.46	69.96	258.23	122.84	64.58	68.48	356.45
F2rate, /s	2.04	1.09	.73	3.28	2.31	.85	1.19	3.77
F2reg, %	60.34	20.65	41.63	95.59	55.54	14.55	40.40	89.81
F2aver, Hz	1727.44	93.17	1438.66	1918.84	1396.74	345.86	782.94	2312.56
F2min, Hz	991.57	313.73	354	1340	601.64	174.52	288	908
F2max, Hz	2387.38	220.72	1898	2811	1944.22	521.25	1593	3290
Voice Parameters								
(F0) in Hz	124.98	14.98	98.97	165.40	213.22	25.54	158.49	262.47

(T0) ms	8.11	.93	6.05	10.10	4.76	.62	3.81	6.31
(Fhi) in Hz	203.78	160.57	102.80	629.41	241.26	63.19	164.88	618.84
(Flo) in Hz	118.18	12.77	91.99	145.57	188.19	44.52	77.28	245.69
(STD) in Hz	6.95	11.63	.62	49.66	8.54	13.22	1.21	56
(vFo) in %	8	17.06	.53	83.47	4.29	7.29	.55	35.33
(vAm) in %	31.66	23.98	5.25	73.93	21.69	17.43	5.77	74.89
Tremor Parameters								
Mftr, %	.60	.48	.21	2.98	.55	.37	.14	1.91
Matr, %	4.13	1.51	1.88	9.41	3.22	1.12	1.66	6.40
Rftr, Hz	5.61	2.80	2.53	9.52	5.11	1.21	3.39	6.06
Ratr, Hz	3.63	1.80	1.94	8.70	4	1.81	1.98	7.14
Pftr, %	46.84	20.03	22.67	76.95	47.97	15.04	26.50	61.54
Patr, %	39.06	23.46	13.51	79.58	40.29	15.01	13.04	60.44
Intonation Stimulability Parameters								
rFo, Hz	137.02	14.88	110.09	176.81	235.32	24.97	177.42	294.14
rTo, ms	7.37	.77	5.66	9.08	4.29	.48	3.40	5.64
rFhi , Hz	180.97	46.68	21.90	354.58	304.18	42.92	219.15	396.01
rFlo, Hz	113.16	14.95	80.87	148.03	189.03	37.26	95.99	240.60
rSTD, Hz	15.11	9.90	5.43	63.38	24.95	10.97	11.91	58.70
rvFo, %	10.93	6.94	3.98	46.44	10.82	5.60	4.81	32.62
rvAm, %	32.87	9.76	17.20	82.20	30.32	5.60	11.98	41.90
Syllabic Rate Parameters								
SLrate, /s	4.25	3.12	1.65	19.59	2.89	.54	2.02	4.51
SLsdur, ms	289.12	77.34	129.09	581.80	320.68	93.91	79.84	474.32
SLpdur, ms	177.78	96.96	103.02	474.80	188.02	71.59	104.08	309.97
SLspk, %	86.36	23.80	14.98	100	89.68	20.80	23.67	100
SLpau, %	31.51	31.30	3.68	99.78	30.33	26.07	3.20	76.33

b) Acoustic variables across gender for age group 30-40 years

Parameters	Gender							
	Male				Female			
	Mean	SD	Min	Max	Mean	SD	Min	Max
DDK Parameters								
DDKavp, ms	226.78	138.25	124.36	833.75	230.67	110.75	115.21	561.04
DDKavr,	5.05	1.74	.79	8.04	4.98	1.88	.89	8.68

/s								
DDKsdp, ms	116.98	114.06	13.47	499.41	51.73	25.79	9.60	98.63
DDKcvp, %	61.52	45.07	14.86	196.14	67.81	48.62	5.10	279.29
DDKjit, %	10.59	12.62	1.79	60.69	15.04	15.21	1.22	63.67
DDKavi, dB	65.46	6.67	55.63	80.03	64.13	6.07	55.86	82.82
DDKsdi, dB	4.47	2.42	.60	8.98	3.55	2.13	.57	8.56
DDKcvi, %	6.64	3.31	1.08	12.64	5.45	3.16	1.02	13.26
DDKmxa, dB	74.91	9.32	57.35	90.31	71.55	8.85	56.63	90.31
DDKava, dB	54.51	6.71	44.75	67.06	54.64	7.57	42.79	66.52
DDKsla, dB	62.36	4.15	55.57	71.06	62.12	3.88	55.70	70.26
F2 Transition Parameters								
F2magn, Hz	490.38	191.82	103.11	769.05	638.88	170.19	102.45	876.32
F2rate, /s	1.83	.63	1.14	3.45	1.74	1.06	1.12	3.64
F2reg, %	71.49	26.10	41.67	96.79	74.29	25.53	43.70	95.79
F2aver, Hz	1653.95	121.18	1361.98	1978.20	1774.96	353.01	1210.90	2341.27
F2min, Hz	701.06	288.79	315	1314	624.88	214.72	295	1438
F2max, Hz	2466.54	214.11	1828	2957	2633.06	643.45	1566	3410
Voice Parameters:								
(F0) in Hz	126.02	22.36	91.41	238.77	202.15	21.73	141.92	248.07
(T0) ms	8.12	1.14	4.19	10.94	5	.59	4.03	7.05
(Fhi) in Hz	163.79	85.54	98.32	629.47	249.83	82.97	149.84	506.49
(Flo) in Hz	117.63	15.44	88.54	163.28	183.21	37.63	75.16	241.11
(STD) in Hz	4.19	5.93	.31	34.12	11.36	16.68	1.71	62.42
(vFo) in %	3.07	3.65	.27	20.35	5.99	9.33	.85	38.96
(vAm) in %	48.15	18.40	10.90	77.05	39.20	22.80	3.29	71.21
Tremor Parameters								
Mftr, %	.61	.35	.18	2.28	.70	.38	.30	1.88
Matr, %	4.45	1.57	1.92	8.57	4.52	1.80	1.76	8.81
Rftr, Hz	3.24	.86	2.02	4.65	5.20	3.25	1.85	10.53

Ratr, Hz	2.27	.37	2	2.70	5.04	3.33	2	11.77
Pftr, %	28.71	11.63	11.70	51.16	37.59	18.30	16.02	72.28
Patr, %	52.93	37.77	10.36	82.44	34.73	21.10	11.15	77.94
Intonation Stimulability Parameters								
rFo, Hz	140.48	17.21	105.83	184.72	226.23	24.29	155.98	275.86
rTo, ms	7.22	.90	5.41	9.45	4.47	.50	3.63	6.41
rFhi , Hz	210.18	64.74	130.07	400.03	296.56	51.57	212.74	396.21
rFlo, Hz	111.42	16.44	75.77	148.71	182.12	30.72	95.60	226.23
rSTD, Hz	17.94	11.28	6.52	63.07	24.25	12.70	6.85	64.52
rvFo, %	12.83	8.06	4.37	44.59	10.57	5.16	3.48	29.56
rvAm, %	33.33	7.18	19.55	53.70	31.57	8.83	5.19	52.36
Syllabic Rate Parameters								
SLrate, /s	3.93	3.98	1.78	30.20	3.79	3.35	1.36	19.62
SLsdur, ms	282.32	85.86	27.20	427.42	272.79	145	5.27	735.05
SLpdur, ms	196.61	114.95	103.74	630.73	199.34	78.82	107.29	398.56
SLspk, %	82.69	21.77	7.98	100	79.85	23.40	6.33	100
SLpau, %	20.67	17.15	3.44	75.12	27.22	23.40	6.33	93.67

c) Acoustic variables across gender for age group 40-50 years

Parameters	Gender							
	Male				Female			
	Mean	SD	Min	Max	Mean	SD	Min	Max
DDK Parameters								
DDKavp, ms	199.82	85.84	109.32	700.43	290.76	220.70	35.04	982.28
DDKavr, /s	5.38	1.43	1.33	9.15	5	3.90	1.02	28.54
DDKsdp, ms	54.68	31.88	12.79	203.54	286.32	423.59	.00	176.96
DDKcvp, %	39.64	20.36	10.74	92.31	72.92	44.74	.00	180.19
DDKjit, %	10.43	15.48	1.30	80.99	28.11	47.65	.00	216.25
DDKavi, dB	64.97	6.21	56.33	83.87	61.87	6	55.41	82.82
DDKsdi, dB	4.08	2.48	.39	9.73	3.38	2.53	.04	10.81
DDKcvi, %	6.12	3.44	.64	13.79	5.23	3.58	.06	14.89
DDKmxa, dB	73.58	8.99	54.30	89.81	68.82	10.22	50.43	88.60
DDKava, dB	53.36	5.83	44.58	66.82	50.74	6.44	42.85	65.38

DDKsla, dB	61.82	3.62	56.17	70.85	60.23	4.19	55.31	70.22
F2 Transition Parameters								
F2magn, Hz	543.94	157.79	127.63	739.33	678.55	236.48	75.97	910.55
F2rate, /s	1.16	.18	.96	1.32	2	1.66	.83	3.18
F2reg, %	77.30	31.49	40.93	95.59	78.05	6.77	73.26	82.85
F2aver, Hz	1649.98	143.56	1428.53	1912.43	1920.71	292.03	1235.40	2310.25
F2min, Hz	589.58	244.37	339	1324	556.76	149.20	382	908
F2max, Hz	2535.06	170.94	2198	2847	2895.82	458.57	1640	3279
Voice Parameters:								
(F0) in Hz	121.12	15	86.38	157.05	198.79	24.64	143.87	253.96
(T0) ms	8.39	1.11	6.37	11.58	5.11	.67	3.94	6.95
(Fhi) in Hz	192.56	111.55	87.86	522.02	313.12	135.66	173.52	624.72
(Flo) in Hz	113.86	15.97	68.04	144.06	172.43	38.48	92.49	229.08
(STD) in Hz	7.20	10.99	.60	51.35	18.62	19.70	1.52	67.44
(vFo) in %	6.15	9.25	.63	38.35	9.55	10.44	.72	34.75
(vAm) in %	51.02	19.69	7.46	83.22	42.18	17.45	4.31	72.99
Tremor Parameters								
Mftr, %	.69	.41	.24	2.06	.87	.66	.19	3.56
Matr, %	4.29	1.88	2.10	12.44	5.16	1.78	1.59	9
Rftr, Hz	5.46	.83	4.44	6.67	6.17	3.95	2.82	12.87
Ratr, Hz	2.83	.71	1.87	3.51	3.48	1.19	2.41	5.41
Pftr, %	37.26	21.88	22.04	76.95	60.65	79.07	10.38	262.59
Patr, %	26.64	10.43	16.70	39.30	26.97	25.77	3.81	77.95
Intonation Stimulability Parameters								
rFo, Hz	140.23	19.91	96.11	180.03	215.76	27.16	167.05	266.08
rTo, ms	7.27	1.04	5.56	10.41	4.70	.59	3.76	5.99
rFhi , Hz	241.49	81.81	133.90	400.46	310.73	56.34	220.36	399.55
rFlo, Hz	111.83	21.40	74.21	168.86	167.55	42.48	68.18	226.23
rSTD, Hz	23.66	17.24	6.11	78.52	26.27	12.04	7.61	54.62
rvFo, %	17.01	12.32	4.84	52.42	12.45	6.34	3.57	29.67
rvAm, %	36	7.50	19.53	55.54	33.34	8.04	5.19	59.23
Syllabic Rate Parameters								
SLrate, /s	3.24	1.28	1.56	9.53	4.15	4.76	1.46	30.44
SLsdur, ms	305.79	81.37	154.35	569.15	282.75	105.60	66.06	591
SLpdur,	263.21	199.0	106.33	798.54	219.59	124	108.51	653.85

ms		1						
SLspk, %	75.12	26.25	13.04	100	69.38	27.97	4.50	100
SLpau, %	28.65	28.01	4.70	95.10	35.15	27.61	3.29	95.50

d) Acoustic variables across gender for age group 50-60 years

Parameters	Gender							
	Male				Female			
	Mean	SD	Min	Max	Mean	SD	Min	Max
DDK Parameters								
DDKavp, ms	219.14	113.34	109.32	698.15	268.32	173.95	86.33	982.15
DDKavr, /s	5.28	1.58	1.43	9.15	4.67	1.89	1.02	11.58
DDKsdp, ms	61.75	64.35	11.46	416.42	152.85	158.80	27.87	998.84
DDKcvp, %	38.35	21.88	8.72	97.31	50.35	28.93	1.62	121.79
DDKjit, %	10.39	10.72	1.94	46.31	16.92	23.55	1.17	136.93
DDKavi, dB	65.44	6.63	55.96	80.26	62.60	5.41	55.35	76
DDKsdi, dB	4.33	2.39	.64	9.26	4.44	2.55	.24	10.81
DDKcvi, %	6.44	3.14	1.14	12.24	6.86	3.58	.43	14.89
DDKmxa, dB	74.31	8.60	57.34	87.98	72.38	9.85	55.35	89.75
DDKava, dB	54.54	6.21	45.36	67.97	51.84	6.79	42.16	65.28
DDKsla, dB	61.99	3.69	55.68	68.49	60.63	3.61	55.35	67.53
F2 Transition Parameters								
F2magn, Hz	523.64	189.92	75.02	773.43	691.05	148.45	216.70	918.36
F2rate, /s	1.56	.27	1.11	1.92	4.03	2.51	2.17	6.90
F2reg, %	91.86	4.40	85.09	97.03	53.04	9.59	42.19	60.38
F2aver, Hz	1565.02	180.70	1233.62	1978.20	1792.34	313.46	1191.96	2181.76
F2min, Hz	544.76	200.11	104.88	993	553.65	144.20	357	908
F2max, Hz	2441.21	358.98	1560	2847	2772.60	555.36	1607	3303
Voice Parameters:								
(F0) in Hz	124.27	18.73	90.89	157.94	191.85	30.58	108.84	263.25
(T0) ms	8.19	1.29	6.33	11	5.34	.92	3.80	9.19

(Fhi) in Hz	159.03	79.58	98.48	570.24	271.54	111.62	164.13	605.37
(Flo) in Hz	115.93	18.95	68.02	153.71	173.27	36.65	88.12	245.66
(STD) in Hz	4.99	10.53	.85	58.70	11.76	13.74	1.21	58.93
(vFo) in %	4.68	9.72	.76	50.24	6.29	7.84	.55	32.98
(vAm) in %	44.61	19.65	6.01	73.27	39.81	17.78	13.44	72.99
Tremor Parameters								
Mftr, %	.70	.41	.22	2.45	.66	.26	.26	1.45
Matr, %	4.36	2.15	1.88	11.60	4.71	1.52	2.25	8.24
Rftr, Hz	6.53	3.83	2.70	15.62	3.90	1.67	1.87	7.41
Ratr, Hz	2.25	.86	.48	4	4.37	2.48	1.91	9.52
Pftr, %	33.88	20.52	4.85	68.53	28.30	13.25	10.38	47.01
Patr, %	32.84	13.10	15.61	58.27	50.68	21.61	22.33	78.49
Intonation Stimulability Parameters								
rFo, Hz	143.08	21.67	108.25	181.58	216.09	29.91	164.06	283.89
rTo, ms	7.15	1.09	5.54	9.24	4.68	.60	3.52	6.10
rFhi , Hz	221.25	74.03	135.97	400.64	291.01	57.56	208.68	413.47
rFlo, Hz	112.81	20.33	68.29	149.87	179.94	40.47	83.48	299.38
rSTD, Hz	19.33	15.49	5.43	89.86	22.70	10.85	6.91	56.25
rvFo, %	13.69	10.91	4.01	57.07	10.58	5.33	3.20	30.53
rvAm, %	33.69	6.78	14.88	48.87	35	8.36	20.19	71.31
Syllabic Rate Parameters								
SLrate, /s	3.74	2.14	2.09	14.68	3.25	1.63	1.44	9.44
SLsdur, ms	297.69	89.96	91.27	458.27	297.74	102.11	115.35	677.95
SLpdur, ms	204.13	137.23	109.78	798.54	233.50	136.72	106.48	612.28
SLspk, %	87.21	17.69	22.27	100	70.95	28.77	7.46	100
SLpau, %	14.74	20.73	3.06	77.73	31.49	27.03	2.70	92.54