VOCAL FUNDAMENTAL FREQUENCY IN SPEAKERS OF KANNADA, MALAYALAM AND TAMIL

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University Of Mysore

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April, 2018

CERTIFICATE

This is to certify that this dissertation entitled **"Vocal fundamental frequency in speakers of Kannada, Malayalam and Tamil"** is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech -Language Pathology) of the student Registration Number: 16SLP007. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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April, 2018

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CERTIFICATE

This is to certify that this dissertation entitled "**Vocal fundamental frequency in speakers of Kannada, Malayalam and Tamil**" has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **“**“**Vocal fundamental frequency in speakers of Kannada, Malayalam and Tamil**”**”** is the result of my own study under the guidance of Dr. K. Yeshoda, Reader in Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru, ***Registration No. 16SLP007***

April, 2018

DEDICATED TO……

My Family and

My Guide, Dr K. Yeshoda

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"You gave me your time, the most thoughtful gift of all."- Dan Zadra

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"*Words mean more than what is set down on paper. It takes the human voice to infuse them with shades of deeper meaning."*- Maya Angelou

INTRODUCTION

"Speech is the form of communication in which the transmission of information takes place by means of speech waves which are in the form of acoustic energy. The speech waveform is a result of interaction of one or more source with the vocal tract filter system" (Fant, 1971).

"Voice is one component of speech. Human voice is an important vehicle for communication and intrinsic linguistic and grammatical features of stress and intonation in speech. Voice and speech are exclusively human attribute" (Greene, 1964). The vocal medium of communication is one among the major characteristics which differentiates the human species from other mammals. Within the human population itself, voice serves as a unique identity to each individual, irrespective of having the same age and gender. In other words, every mature voice is a unique character and just as no two faces are same, neither are two voices. Perkin (1977) identified about five non linguistic functions of voice, that is, voice can reveal an individual's identity, personality, emotion, at least some aspects of somatic condition and it can even serve as an aesthetic function. Thus the human voice is inseparably tied up with his emotion and is also greatly influenced by his contact with the outside environment. Deutsch (1991)

hypothesized that listeners acquire an internal representation of pitch classes based on the prevailing pitch range of speech in their linguistic community and that this representation influences both their perception and their speech production. The hypothesis was further proved consistent by Dolson (1994).

Human voice can be studied both qualitatively and quantitatively by perceptual listening and instrumental analysis respectively (Hakkesteegt, Brocaar, Wieringa & Feenstra, 2008). Perceptually the human ears act as the analyzer and differentiate the voice, thus making it possible to identify different speakers just by their voice. The perceptual evaluations are usually carried using voice quality rating scales (e.g., Buffalo Voice Screening Profile, Wilson, 1987). Though tagged as the gold standard to voice analysis, the perceptual evaluation sets certain drawbacks in comparison to the instrumental analysis, one being the inability to quantify the voice. Acoustic analysis of the voice is more objective than auditory methods for screening and voice therapy assessment (Kent, 1976). It is best suited for routine evaluation of laryngeal functions because of its noninvasive nature and ability to define voice quantitatively (Davis, 1979). Acoustic measures are thus considered to be the most reliable means of objective measurement of voice quality (Carding, Wilson, Mackenzie & Deary, 2009).

Pitch is considered as one of the important factor, both etiologically and certainly symptomatically, in voice disorders (Fairbanks, 1940; Brodnitz, 1962; Howard, 1998). The term pitch and frequency needs to be understood separately as *pitch* refers to a perceptual attribute of sound, generally scaled on a high-low continuum whereas *frequency* refers to a physical attribute of certain signals,

essentially, the repetition rate of a recurring wave shape. Vocal fundamental frequency (F0) mirrors the biomechanical characteristics of the vocal folds as they interact with the translaryngeal airflow. The laryngeal structure and the applied muscle forces determine these biomechanical properties. F0 depends on the shape and the volume of the resonating cavity and varies with different vowels (Zinkin, 1968). For the objective evaluation, frequency related measures (e.g., fundamental frequency, frequency range, etc.), amplitude related measures (e.g., habitual intensity, etc.), perturbation related measures (e.g., jitter, shimmer, etc.) and harmonic related measures (e.g., harmonic to noise ratio, etc.), are the wide varieties of acoustic measures used by the researchers (Dejonckere & Lebacq, 1996; Rabinov, Kreiman, Gerratt & Bielamowicz, 1995; Piccirillo, Painter, Fuller, Haiduk & Fredrickson, 1998; Wolfe & Fitch, 1995).

It is expected that the vocal pitch will be appropriate in some ill-defined way to a speaker's age and sex (Michel & Wendahl, 1971; Wolfe, Ratusnik, Smith & Northrop, 1990) and perhaps to body type, social situation, emotional state, and other factors as well (Hecker, von Bismarck & Williams, 1968; Griffin & Williams, 1987; Ruiz, Legros & Guell, 1990; Przybyla, Horii & Crawford, 1992).

There has been a longstanding interest in understanding the F0 characteristics of speech (e.g., Weaver, 1924). The speech performances are denoted based on the F0 range, this simply attributes to the F0 range at spoken communication and does not contribute to speaker's vocal range (i.e., the range of fundamental frequencies physically possible to an individual) and is usually

referred to as the *Speaking Fundamental Frequency or SF0* (Baken & Orlikoff, 2000). Evaluation of F0 during speech shows whether a given speaker's voice is really different from that of comparable speakers or whether the listener's perception of abnormality is based on other aspects of voicing. Though it's largely affected by speaker's age and gender, the type of communication being undertaken, the speaker's emotional state, background noise, reading aloud, talking on the telephone, the degree of intoxication if the speaker has been drinking alcohol, could also be some related factors (Greene & Mathieson, 2001).

Speech is mostly not monotous, thus a speaker uses a range of fundamental frequencies in speech production. Thus there are two basic and general properties associated with SF0: the frequency average and variability. The average SF0 denotes the "average" fundamental frequency value, and this could be mean SF0, median SF0 or modal SF0. SF0 variability can be represented in a simple way as the SF0 range (commonly represented in semitones) which is the difference between the highest and lowest F0 of a given sample. Other measures like mean/median F0 has been adopted and used as an uncontroversial measure in various cross language studies to sort the differences in F0 range (e.g., Altenberg & Ferrnad, 2006; Hanely, Snidecor & Ringel, 1966).

An adequate sample is required for determining the SF0, which could be obtained from a spontaneous speech sample or from a standardized reading passage. The influence of factors like reading ability and style can bring about the variability in results, while carrying out a reading task (Fairbanks, Herbert & Hammond, 1949; Fairbanks, Wiley & Lassman, 1949). Snidecor (1943), Mysak

(1959), Saxman and Burk (1967), Hollien and Jackson (1973) and Hollien, Hollien and de Jong (1997), carried out studies were both the tasks- reading and spontaneous speech were compared. All found mean SF0 during reading was slightly higher than the mean SF0 during spontaneous speech task. Baken and Orlikoff (2000) emphasized the brighter side of using standard reading passage over an unscripted passage in the measure of speaking fundamental frequency. Reinforcing to Baken and Orlikoff (2000), Torgerson (2005) recently found no differences between read sentences and spontaneous speech in Mandarin language in terms of F0 and related measures. With limited variability among the tasks, it's a better preference to use a standardized passage to control other confounding variables among the speakers.

Studies have reported the variability in SF0 across speakers of different languages or dialects, thus adding voice as an identity to an individual (Dolson, 1994). The vocal fundamental frequency is also reported to vary with the social groups within a language (Crystal, 1969; Loveday, 1981; Graddol & Swann, 1983; Henton, 1989; Podesva, 2007). Studies have reported the variation in F0 with various speaker oriented factors such as the effects of age, gender, height, weight, ethnicity and regional accent (Chen, 2005; Diana Deutsch, Le, Shen & Henthorn, 2009; Hollien et al., 1997; Nishio & Niimi, 2008; Van Dommelen & Moxness, 1995). Other than the organic factors which majorly contribute to this difference (e.g., body size or race-based vocal tract differences, Awan & Mueller, 1996) studies have also correlated these differences to either linguistic or cultural

aspects but very little investigation is done on the phonetic basis to the same (Deutsch, Le, Shen & Henthorn, 2009).

It is of great practical interest then, to determine and to understand whether there are any differentiated effects of language in the phenomenon of voice production and vocal frequency in the South Indian context.

Aim of the Study

The main aim of the present study is to understand and compare vocal fundamental frequency and its related measures in speakers of south Indian languages of Kannada, Malayalam and Tamil.

CHAPTER II

REVIEW OF LITERATURE

Voice has been defined as "the laryngeal modulation of the pulmonary airstream, which is further modified by the configuration of the vocal tract" (Brackett, 1971). The vocal mechanism plays an important role while speaking. "The quality and loudness of voice are mainly dependent upon the frequency of vibration. Hence frequency is an important parameter of voice" (Anderson, 1961). An individual's voice mirrors his character and personality. Lass, Brong, Ciccolella, Walters and Maxwell (1980) reviewed several studies which have shown that it is even possible to identify the speaker's age, sex, race, socio-economic status, social features, height and weight based on voice. Research in the field of variation in voice with respect to cross language, cross dialects of a language and across various cultures has primarily focused on the variations across the acoustic measures of fundamental frequency and intensity.

The Language Influence on Voice

The earliest studies to explore the differences in acoustic analysis based on dialects and languages have been the contributions made by relatively few researchers. Atherton and Gregg (1929), carried out a pilot study to understand the acoustic variations related to the dialects of American English, which was further studied extensively by Hanley (1951). Parmenter and Blanc (1993) carried out acoustic comparison of French and English native speakers for reading task.

The authors concluded that the pitch was an important element of accent in French where as the intensity mattered in case of English speakers. French was reported have greater pitch variability (41.6%) than English.

Vocal fundamental frequency variation across languages was carried out by Hanley, Snidecor and Ringel (1966) and Hanley and Snidecor (1967). In the former study, samples from three groups of subjects, each comprising of eight young men were taken. The three groups were native speakers of Spanish, Japanese, and American English. All the participants indulged in both reading standardized passage (Rainbow Passage; Fairbanks, 1940) and spontaneous speech which was further subjected to instrumental analysis. Spanish and Japanese native speakers had higher pitch level than the native English speakers and a vice versa trend was observed in terms of sound pressure level. On a pitch continuum from low to high pitch, the mean pitch level took the order of American English, Spanish, and Japanese. The Japanese and the English speakers had greater pitch variability than Spanish speakers and Spanish and Japanese speakers had greater sound pressure level variability in reading task. Overall the authors also concluded that reading task had higher pitch and more pitch variability than spontaneous speaking task. Whereas the latter study of Hanley and Snidecor (1967) compared eight female native speakers of American English, Spanish, Japanese and Tagalog on reading (The Rainbow passage and a propositional prose passage written in native languages) and spontaneous speech. Results indicated that the Tagalog speakers expressed a greater usage of pitch variability than other language speakers. The Tagalog speakers also reported

higher phonation/Time ratio, whereas the American English and Japanese had low ratios. The results marked contrast with the results of the comparable male speakers from the former study, who indicated significant differences among the Japanese, Spanish and general Americans.

Chen (1972) compared the mean, standard deviation and range of F0 of 4 English and 4 Mandarian speakers (2 males and 2 females in both the languages) on reading task. The female speakers of the tonal Mandarian language were noted to have wider F0 ranges and larger standard deviations. The Mandarian language female speakers had lower mean when compared to that of the English speaking counterparts, but the trend was same among the male speakers of both languages. A study by Eady (1982) contradicts these results. He compared several measures of F0 among Mandarian Chinese and American English male speakers and concluded the mean F0 and measures of F0 fluctuation to be greater for Mandarian male speakers than English speakers. However there was no difference among the speakers of both the languages in terms of standard deviation.

Majewski, Hollien and Zalewski (1972) concluded that young Polish native speakers were noted to have higher mean F0 in comparison to the previously reported values of American native male speakers, using standardized reading passage and related the differences to cross cultural factors.

Studies on comparison of the speakers of Japanese versus English speakers (Loveday, 1981; Yamazawa & Hollien, 1992; Todaka, 1993) indicated that both male and female speakers employed higher F0s in Japanese than in

English. The Japanese female speakers exhibited significant higher mean fundamental frequencies than the American speakers in readings tasks, based on a study done by Yamazawa and Hollien (1992). The authors justify it to the 'tone' aspect of Japanese language to certainly account for the addition of higher frequencies to SFF distribution among these speakers.

Chen (2005) compared frequency and intensity related measures of tonal languages, Mandarian versus Min (Taiwanese) and also further extended the comparison of the same data with the non tonal American English language, based on reading task. Among the tonal versus non tonal language comparison, the maximum range of speaking intensity for both the sex were greater for Mandarin and Min speakers than for American English speakers of comparative gender, based on the earlier findings (Awan, 1993; Benjamin, 1981; Snidecor, 1951). The variability of speaking fundamental frequency for female speakers of Mandarian and Min was smaller than the findings of few of the earlier studies (Saxman & Burk, 1967; Stoicheff, 1981; Brown, Morris, Hollien & Howell, 1991; Hollien, Hollien & de Jong, 1997) while was greater than what was reported in certain other studies (Fitch & Holbrook, 1970; Hudson & Holbrook, 1981; Fitch, 1990) for female American speakers.

Mennen, Schaeffler and Docherty (2012) analysed various measures of F0 range in 30 female speakers of English and German native respectively, based on reading tasks. F0 range was analysed along level (i.e., overall F0 height) and span (extent of F0 modulation within speech sample). Significant cross language

differences in both dimensions of F0 range was obtained, but the effect sizes were found to be larger for span than for level.

Keating and Kuo (2012) carried out a study comparing the speaking fundamental frequency profiles of English and Mandarian speakers across both the genders. The authors quoted differences in the F0 profiles which was but noted to be highly dependent on the particular speech samples compared. The physiological F0 ranges of the speakers (determined from tone sweeps) hardly differed between the two languages, making it easy for comparison. However the use of F0 in single utterances differed across the languages with Mandarian speakers having higher maximums and means and larger ranges. Even with only the Mandarian high falling tone was compared with English, both languages were similar across prose reading task with differences only in the mean F0 and Mandarian was reported to have higher mean F0. To conclude, in the reading task, the average F0 is higher in Mandarian than in English and greater F0 range for Mandarian only when single word utterances was considered.

The Influence of Task on Voice

Studies have very well established higher mean F0 for speaking when compared to phonation and also higher SF0 for females when compared to males (Hudson & Holbrook, 1981). Studies have also been carried out in this context to understand the F0 for the task of phonation and speaking in both males and females, in the Indian context as well. The measurement of F0 in phonation and

speaking is important in assessing neuromuscular development and diagnosis and treatment of various voice disorders (Gopal, 1986). Nataraja, Jagadish and Kumar (1984) measured the F0 across different tasks- phonation, reading, singing and speaking and also the optimum frequency in 30 normal males and females respectively. The investigators observed that F0 increased from phonation to singing with speaking and reading in between. Sreedevi (1987) compared the F0 across two tasks - phonation of vowel /a/ and while speaking 6 sentences spontaneously, for 50 males and 50 females respectively. For the phonation task male native speakers had lower mean F0 compared to females native speakers. For the SF0, similar trend was observed with female speakers having greater SF0 when compared to male native speakers. The speaking fundamental frequency was calculated across wide age range (16-65 years), for sentence repetition task, for 100 native Kannada speakers (50 males & 50 females respectively) by Gopal (1986). The speaking fundamental frequency was higher for females when compared to males across all the age groups. These differences were further attributed to difference in vocal system in males and females.

With this background, the aim of the present study is to shed light on the variation in vocal fundamental frequency in a cross linguistic context, as there is very minimum literature with regard to the vocal fundamental frequency across languages in the Indian scenario for phonation and reading task. Hence, this study is planned to inquire into the F0 variations across a few south Indian (Dravidian) languages, namely, Kannada, Malayalam and Tamil.

Objectives of the Study

The present study was planned with the following objectives:

1. To measure the vocal fundamental frequency and its related measures in speakers of south Indian languages of Kannada, Malayalam and Tamil.
2. To compare vocal fundamental frequency and its related measures across the speakers of Kannada, Malayalam and Tamil.

CHAPTER III

METHOD

3.1 Participants

A total of 90 participants, 30 in each of the three language groups, with equal female (15 female) and male (15 male) representation, in the age range of 28- 45 years (the mean age was 36.1years) were recruited for the present study. The participants chosen were either a native speaker of Kannada, Malayalam or Tamil and were thus sub grouped based on the native languages spoken. To maintain homogeneity and for convenience, the participants were selected from a single district from the states of Karnataka (Mysore), Kerala (Kannur) and Tamil Nadu (Coimbatore), respectively. The participants were well informed about the purpose of the study and a prior consent was taken before their participation in this study. A basic subject history was carried out to ensure that all the 90 participants fulfilled the following criteria:

3.1.1 Inclusion criteria

- Native speakers of Kannada, Malayalam and Tamil who are the residents of the mentioned district in the respective states.
- Perceptually normal voice quality and speech skills based on screening protocols (e.g., Consensus Auditory-Perceptual Analysis of Voice, ASHA, 2002). Proficiency in speaking and reading in the native language, preferably with a bachelor's degree as the educational status were enrolled.

3.1.2 Exclusion criteria

- Professional voice users.
- Participants with long term exposure to alcohol and tobacco consumption (history of withdrawal within past 5 years).
- Participants with history of speech, language, hearing, neurological or cognitive deficits.
- Participants with upper respiratory tract infections, asthma, and or any allergic conditions at the time of recording.
- Participants, who reported endometriosis, early menopause and hyperthyroidism during the interview, were excluded from the study.

3.2 Tasks

3.2.1 Phonation: Phonation of vowel /a/ for at least 5 second at comfortable pitch and loudness following a deep inhalation (the task was first demonstrated by the experimenter). Three iterations were taken for the phonation task.

Instructions:All the participants were instructed to sit comfortably, take a deep breath and then phonate /ah/ as long as possible, while exhaling the air. The participants are expected to phonate continuously at their comfortable loudness and pitch, without any perceived voice breaks, in one single deep breath.

3.2.2Reading:100 word standard passages in Kannada, Malayalam and Tamil (Savithri & Jayaram, 2008) were used and all the subjects were instructed to read.

Instructions: All the participants were instructed to sit comfortably, take a deep breath and then read the standardized passage presented to them (respective to their language). Participants were expected to read the passage at their comfortable loudness and pitch.

3.3 Procedure

All the tasks were recorded individually in a quiet room using a digital recorder (Olympus Digital Voice Recorder LS-100). The samples were recorded directly on to the digital voice recorder. The microphone was positioned at the distance of 10cms from the subject's mouth during the recording in a comfortably seated position. A phonation task followed by the reading task was carried out after appropriate instructions.

3.4 Analyses

All the samples were subjected to acoustic analysis. The Multi Dimensional Voice Program (MDVP) and Real Time Pitch (RTP) softwares of the Computerized Speech Lab (CSL) 4500 model (KAY PENTAX, New Jersey, USA) were used for analyses of the data. Phonation samples were subjected to MDVP analysis and fundamental frequency and its related parameters were extracted. Reading samples were analyzed using RTP and fundamental frequency and its related measures were extracted.

3.4.1 Phonation

The following acoustic measures (Fundamental Frequency Measures) were extracted from phonation after MDVP analysis:

1. Mean Fundamental Frequency (MF0): Average value of all extracted period to period fundamental frequency values
2. Highest Fundamental Frequency (FHi): Highest fundamental frequency value in phonation.
3. Lowest Fundamental Frequency (FLo): Lowest fundamental frequency value in phonation
4. Standard Deviation of Frequency (STD): Variation of fundamental frequency within the analysed voice sample.

3.4.2 Reading

The following acoustic measures (Fundamental Frequency Measures) were extracted for reading after RTP analysis:

1. Mean F0 (SMF0): Mean F0 reports the harmonic mean. It is calculated using the formula M=n/ (1/f1+1/f2+…….+1/fn), where n is the total number of voice periods and f1…fn are the frequency values for each period. For pitch synchronous F0 extraction, the mean F0 is not weighted towards the higher frequency as is the arithmetic mean. Mean F0 is the inverse of Mean Period.
2. Minimum F0 (SMin F0): One of the extremes of data distribution reflecting the lower limit, or lowest value, among the captured data.It is the lowest pitch value recorded.

3. Maximum F0 (SMax F0): One of the extremes of data distribution reflecting the upper limit, or highest value, among the captured data. It is the highest pitch value recorded.
4. Standard Deviation F0 (SD F0): This is the measure of variability in the data. It reflects the spread of the data, or the average amount of which the data deviates from the harmonic mean. Standard Deviation of F0 computed in Hz on all F0 values in the selection areas. It indicates how much variation in pitch occurred around the average value and is a useful indicator of monotonicity.

3.5 Statistical Analysis

SPSS version 20 was used for statistical analysis of the extracted acoustic data. Descriptive statistics was employed to find the mean and standard deviation of the extracted acoustic measures. Multivariate analysis of variance was carried out to find out the significance depending on the extracted parameters.

CHAPTER IV

RESULTS AND DISCUSSIONS

This particular study was focused to understand and compare the vocal characteristics of speakers of south Indian languages, namely, Kannada, Malayalam, and Tamil based on the fundamental frequency (F0) related information measures. A total of ninety subjects (N=30, 15-Males and 15-females from each language groups) participated in the study. The measures of vocal fundamental frequency (F0) were assessed for both phonation and reading tasks. The Multi Dimensional Voice Program (MDVP) and Real Time Pitch (RTP) softwares of the Computerized Speech Lab (CSL) 4500 model (KAY PENTAX, New Jersey, USA) were used for analyses of the phonation and reading samples respectively. Overall eight F0 related measures were extracted, four from MDVP and four from RTP respectively. The analysed data were further subjected to statistical analysis using SPSS software version 20.

Normality check for data

Through box plots, eight samples were identified and removed as outliers, out of the 90 samples. The eight samples constituted six males (two from each of the three language groups) and two females (one from Tamil and Malayalam). After the removal of outliers there were 82 samples in total (n=27 for Malayalam; n=27 for Tamil, n=28 for Kannada).

In order to determine the normality of the selected samples (n=82), Shapiro Wilk's test of normality was carried out with respect to the independent

variables- gender and language groups. It was revealed that all the parameters followed normal distribution with p> 0.05 for both the independent variables (language groups and gender).

Further, the extracted acoustic measures for phonation and reading tasks were subjected to descriptive statistics to obtain the mean, the standard deviation (SD) and the median. The test of significance was administered to investigate whether there was any significant relationship between the fundamental frequency measures and the variables undertaken. The results of the study are summarized in tables 1-8 and will be discussed under the following sub-headings:

I. Fundamental Frequency (F0) Measures for Phonation

II. Fundamental Frequency (F0) Measures for Reading

I. Fundamental Frequency (F0) Measures for Phonation

The mean, standard deviation and median values of fundamental frequency related information measures obtained in each language for both genders are presented in table 1.

When gender influence across the three languages were considered, Kannada speaking females had the highest mean and median values followed by Malayalam and Tamil female native speakers for MF0, HF0, and LF0. For STDF0, females of Kannada language had the highest mean and median values followed by the female speakers of Tamil and then Malayalam. Among males, the mean and median values of MF0, HF0, and LF0 were highest for Malayalam native speakers followed by Kannada and then Tamil native speakers. For mean

STDF0 was highest for Tamil male speakers followed by Kannada and Malayalam male speakers whereas, the median STDF0 was highest for native speakers of Tamil followed by Malayalam and Kannada.

Table: 1 Mean, SD and Median for F0 and related measures for phonation in males and females across three languages

Parameters	Groups	Gender	N	Mean	SD	Median
MF0	Malayalam	Male	13	128.29	10.32	126.49
		Female	14	210.99	28.01	208.85
	Tamil	Male	13	116.73	12.85	114.94
		Female	14	201.25	25.38	202.30
	Kannada	Male	13	119.73	18.69	119.20
		Female	15	214.17	20.31	217.56
HF0	Malayalam	Male	13	130.77	10.22	130.02
		Female	14	215.44	29.06	213.14
	Tamil	Male	13	120.47	13.70	119.16
		Female	14	207.50	24.87	208.55
	Kannada	Male	13	123.40	19.96	123.10
		Female	15	220.39	21.31	226.60
LF0	Malayalam	Male	13	125.21	10.72	124.61
		Female	14	206.77	26.75	204.31
	Tamil	Male	13	112.77	12.84	111.62
		Female	14	196.40	26.20	198.51
	Kannada	Male	13	116.73	17.82	117.92
		Female	15	209.41	20.37	213.82
STDF0	Malayalam	Male	13	1.16	.23	1.18
		Female	14	1.58	.55	1.64
	Tamil	Male	13	1.56	.64	1.63
		Female	14	1.90	.62	1.87
	Kannada	Male	13	1.37	.67	1.12
		Female	15	2.27	.73	2.20

Parametric tests were carried out to understand statistical significance as the data (n=82) followed normal distribution. For this, two way Multivariate Analysis of Variance (MANOVA) was carried out. The results of overall multivariate test are presented in table 2.

Table 2: Results of tests of significance for F0 and related parameters in phonation at different levels

Levels	F	p value	Effect size
Groups	2.17	.03	.10
Gender	92.86	.00	.83
Groups* Gender	82	.58	.04

Table 2 depicts the overall results of multivariate tests across language groups, genders and also the group- gender interaction, for the selected sample (n=82). The group effects of language revealed p=0.03 (p< 0.05), indicating significant difference across the three language groups. The gender effect also showed a significant difference at p=0.00 (p<0.05). For group and gender interaction, p=0.58 (p>0.05), thus indicating no significant language and gender interaction effect.

Subsequently Analysis of Variance (ANOVA) was done to check the effect of group, gender and group-gender interaction, for the specific F0 measures, which is depicted in table 3.When gender was considered, all the parameters- MF0, HF0, LF0 and STDF0 had p=0.00 (p=<0.05), indicating a significant difference between males and females (Table 3). There was no significant gender and language group interaction found (Table 2), which was further reflected in table 3 also as p> 0.05 for all the four parameters.

Table3: Results of tests of significance of F0 and related parameters for between group effect for phonation task

Levels	Parameters	F	p value	Effect Size
Groups	MF0	1.97	.14	.04
	HF0	1.49	.23	.03
	LF0	2.30	.10	.05
	STDF0	4.24	.01	.10
Gender	MF0	371.51	.00	.83
	HF0	369.95	.00	.83
	LF0	367.58	.00	.82
	STDF0	16.93	.00	.18
Groups * Gender	MF0	.65	.52	.01
	HF0	.66	.51	.01
	LF0	.58	.56	.01
	STDF0	1.75	.18	.04

From table 3, it was noted that among the different language groups, only STDF0 had $p=0.01$ ($p<0.05$), thus contributing to a significant difference across the three language groups.

The results for phonation in general indicated that the mean values were lowest for Tamil native speakers for all the F0 measures except for the STDF0, when compared to Malayalam and Kannada native speakers. This trend was noted in both male and female native speakers of the three languages for the phonation.

When gender was considered, there was significant difference for all the parameters in all the three languages with highest mean values for female subjects when compared to males. These results reinforce the results of study done by Traunmuller and Eriksson (1997), where the mean F0 for vowels were 109.4Hz and 209.4Hz for males and females respectively. There is ample evidence of studies in the Indian context also wherein, higher mean F0 in phonation of vowel /a/ for female native speakers are reported when compared to

male speakers (Sheela, 1974; Nataraja, Jagadish & Kumar 1984). Vanaja (1986) reported that males have lower mean F0 when compared to female speakers for all the vowels after comparing F0 for phonation of different vowels across age groups 16-65 years. This result is in agreement with the results obtained for phonation in the present study. The variations in vocal systems of males and females could be attributed as the reason for these differences (Peterson & Barney, 1952; Mysak, 1959).

Further, when gender and language were considered, it was noted that Malayalam male speakers showed highest mean values for all the measured F0 parameters except for STDF0, followed by Kannada and then Tamil male speakers. The higher mean for STDF0 in native Tamil speakers indicates greater variation in F0 range. Similarly females, it was noted that speakers of Kannada language showed highest mean values followed by Malayalam and Tamil native speakers for all measures, except for STDF0, which was greater for Malayalam.

II. Fundamental Frequency (F0) Measures for Reading

The mean, standard deviation and median values of fundamental frequency information measures obtained in each language for both genders are presented in table 4.

It was noticed that female Tamil speakers had the highest mean value followed by Kannada and Malayalam languages native speakers for MF0 and HF0 when gender and language effect were considered. For LF0, female native

speakers of Malayalam had the highest mean and median value followed by Tamil and then Kannada female native speakers. For STDF0, Kannada female speakers had the highest mean and median followed by Tamil and then Malayalam female native speakers. Among males, the mean value of MF0 and STDF0 were highest for Kannada speakers followed by Malayalam and then Tamil native speakers. The mean and median HF0 and LF0 were highest for Kannada male native speakers followed by Tamil and Malayalam male native speakers.

Table 4: Mean, SD and Median for F0 and related measures for reading in males and females across three languages

Parameters	Groups	Gender	N	Mean	SD	Median
MF0	Malayalam	Male	13	132.61	14.00	133.62
		Female	14	196.09	16.69	196.62
	Tamil	Male	13	131.11	9.96	127.26
		Female	14	218.04	18.84	218.49
	Kannada	Male	13	136.91	20.95	138.21
		Female	15	213.44	22.74	219.85
HF0	Malayalam	Male	13	324.71	56.00	321.75
		Female	14	348.74	29.68	357.33
	Tamil	Male	13	343.18	29.11	349.26
		Female	14	373.32	18.59	374.66
	Kannada	Male	13	365.80	12.82	365.12
		Female	15	365.93	23.35	370.38
LF0	Malayalam	Male	13	77.76	6.89	75.45
		Female	14	94.30	14.17	94.32
	Tamil	Male	13	79.74	5.67	77.68
		Female	14	87.33	14.34	84.67
	Kannada	Male	13	81.13	7.05	81.68
		Female	15	85.71	13.14	82.97
STDF0	Malayalam	Male	13	32.39	16.75	30.59
		Female	14	24.76	8.08	22.41
	Tamil	Male	13	30.90	6.87	31.13
		Female	14	32.61	7.147	31.88
	Kannada	Male	13	36.33	6.703	37.00
		Female	15	34.17	11.20	31.99

The data (n=82) followed normal distribution hence parametric tests were carried out to understand statistical significance. Two-way Multivariate Analysis

of Variance (MANOVA) was carried out. The overall multivariate test results are presented in table 5.

Table 5: Results of tests of significance of F0 and related parameters in reading at different levels

Levels	F	p value	Effect size
Groups	2.60	.01	.12
Gender	90.54	.00	.83
Groups* Gender	2.40	.01	.11

Table 5 depicts the results of overall multivariate test carried out for the language groups, gender and also for group-gender effect for the selected samples (n=82). Group effect for language revealed p=0.01 ($p<0.05$), indicating a significant difference across the three language groups. For gender effect, p=0.00 ($p<0.05$) indicating a significant difference across the genders. For the group and gender interaction effect, a significant value at p=0.01 ($p< 0.05$) was obtained, indicating a significant language and gender interaction.

Analysis of Variance (ANOVA) was done to check the effect of group, gender and group-gender interaction and the same is depicted in table 6. When gender was considered, for the parameters- MF0, HF0 and LF0 showed p=0.00, p=0.01, p=0.00 respectively ($p<0.05$), indicating a significant difference across males and females for these parameters (table 6).However, STDF0 had p=0.23 ($p>0.05$) indicating no significant difference across males and females. A

marginal significance was seen for group and gender interaction, for MF0 with p=0.06, as depicted in table 6.

Table 6: Results of tests of significance of F0 and related parameters for between group effect for reading task

Levels	Parameters	F	p value	Effect size
Groups	MF0	3.14	.04	.07
	HF0	6.44	.00	.14
	LF0	.48	.61	.01
	STDF0	3.00	.05	.07
Gender	MF0	365.96	.00	.82
	HF0	6.93	.01	.08
	LF0	15.35	.00	.16
	STDF0	1.45	.23	.01
Groups * Gender	MF0	2.91	.06	.07
	HF0	1.79	.17	.04
	LF0	2.16	.12	.05
	STDF0	1.45	.23	.03

Reading task in general revealed that female participants had highest mean values for all the parameters, across all the languages except for STDF0 in Malayalam and Kannada compared to males. This is in agreement with the results of Hudson and Holbrook (1981) who reported mean modal F0 for reading task to be higher for females (mean =193.10Hz) when compared to that of males (mean=110.15 Hz), based on a study done on 100 blacks ranging in age from 18-29 years.

Among the languages, it was found that Malayalam showed lowest mean values for all F0 related parameters except LF0 in female participants compared to Tamil and Kannada languages. However, in male participants a mixed trend was noticed wherein lower mean values were obtained for Tamil language for MF0 and STDF0 but Malayalam for HF0 and LF0. Concurrence to the above

results (ignoring the languages considered) can be drawn from Mennen, *et al.*,(2012) who compared the fundamental frequency range across English and German language and found that F0 related measures could be influenced by phonological/ phonetic conventions of the language spoken and need not be solely associated with physiological factors as often assumed.

Female in general are more expressive in their speech characteristics, using complete articulatory gestures/ postures, open mouth articulation and using maximum prosody when compared to male speakers. A parallel could be drawn from Fairbanks and Pronovast (1939) and Fairbanks (1940) explanation that the variations in F0 and the F0 range can be related to intent of the speaker. The spread of frequency range can be associated to the mood of the speaker as stated by the results of Skinner (1935) conclusion that a cheerful animated speech exhibits increased range than serious thoughtful speech. This probably could explain the results that indicated higher mean values for all F0 parameters in reading for females, in the present study. Also further support could be from Trudgill (1974) suggestion that three influences of individuals that affects SFF behavior. The first one is attributed to individual's physical and anatomical disposition. The second influence derives from the cultural expectations and one's societal status. The third influence is associated to the more rapid fluctuations in SFF connected with intonation.

Female native speakers of Malayalam had lower mean for most F0 and its related parameters. Probable reason could be that Malayalam has more number of stops including nasal stops when compared to Kannada and Tamil. Also native

speakers of Malayalam are considered to possess more nasality component in connected speech compared to the other two languages. However, the effect of this was not noticed in male participants of Malayalam language.

The probable justifications could be borrowed from Majewski et al., (1972) wherein they attempted to rule out the probable reason for such language based differences, from their cross linguistic study using Polish and English speakers by correlating the influence of height, weight and height-weight interaction for SF0 in reading. Results indicated no significant relationship and hence the reasons for such cross linguistic variations were not clear and further investigations were suggested.

When the F0 related measures were compared across phonation and reading tasks, it was noticed that the mean MF0was highest for reading compared to phonation in all the three languages. Similar findings of mean MF0 being highest for reading when compared to phonation were reported by Keating & Kuo (2012); Nataraja, Jagadish and Kumar (1984) and Sreedevi (1987).

These results are also in line with the well established fact of differences in F0 owing to different vibration rates of vocal cords in males and females. Such sex differences in rate of vocal folds vibrations are attributed to the differences in the vocal systems in males and females. Titze (1989) stated that the difference in voice characteristics between males and females can be attributed to various factors such as overall size, vocal fold membrane length and elastic properties, with mean length of vocal fold contributing to F0 characteristics.

The highlights of the present study were, significantly higher F0 related parameters in females when compared to males across all the three languages for phonation and reading. When influence of language was checked, participants with Tamil as their native language showed lower mean values for most F0 related parameters in phonation. But in reading, lower mean values for most F0 related parameters was noted in participants with Malayalam as their native language. It was also interesting to note that the MF0 varied with task and it was found to be highest in reading when compared to phonation. These results signify the culture, language, speaker related factors play a major role when connected speech tasks, such as, reading is considered.

The results of the present study emphasize upon importance of the task to evaluate F0 and related measures as they may reveal that task specific differences. Sustained phonation assesses the symmetry and control of vocal folds vibrations while reading evaluates the coordinated variations in the control of vocal folds vibrations within a specified time frame. Hence, the choice of task is always under purview of the research question that needs to be addressed.

CHAPTER V

SUMMARY AND CONCLUSIONS

The aim of the present study was to understand and compare the fundamental frequency (F0) and related measures in native speakers of south Indian languages, namely, Kannada, Malayalam, and Tamil. A total of ninety subjects (N=30, 15-Males and 15- females from each language groups) participated in the study. The measures of vocal fundamental frequency (F0) were assessed for both phonation and reading tasks. The Multi Dimensional Voice Program (MDVP) and Real Time Pitch (RTP) softwares of the Computerized Speech Lab (CSL) 4500 model (KAY PENTAX, New Jersey, USA) were used for analyses of the phonation and reading samples respectively. Eight F0 related measures from MDVP and four from RTP respectively were extracted. The analysed data were further subjected to statistical analysis using SPSS software version 20.

The results in general indicated that the mean values were lowest for Tamil native speakers for all the F0 measures except for the STDF0, when compared to Malayalam and Kannada native speakers in phonation. This trend was noted in both male and female native speakers of the three languages for the phonation. However, in reading it was noticed that female Tamil speakers had the highest mean value followed by Kannada and Malayalam languages native speakers for MF0 and HF0. LF0 showed higher mean and median value for female native speakers of Malayalam followed by Tamil and Kannada. In males, the mean MF0 and STDF0 were highest for Kannada speakers followed by

Malayalam and Tamil native speakers. The mean and median HF0 and LF0 were highest for Kannada male native speakers followed by Tamil and Malayalam male native speakers.

The summary of the results of the present study are (a) significantly higher F0 related parameters in females compared to males in all the three languages for phonation and reading. (b) When language was considered, participants with Tamil as their native language showed lower mean values for most F0 related parameters in phonation. But in reading, lower mean values for most F0 related parameters was noted in participants with Malayalam as their native language. (c) MF0 varied with the task and it was found to be highest in reading when compared to phonation.

The choice of task is a significant factor in assessing F0 and related parameters as sustained productions check the control and symmetry of vocal folds vibrations and reading evaluates the variations possible vocal folds vibrations within a specified time. Crucially the different speech samples show different results. So whether any set of considered languages appear to be similar/ different in F0 related profiles very much depend on the task as well as the measures extracted. However, the influence of culture, language, and speaker related factors also must be considered in interpretation of the results.

Implications of the Study

1. To understand the influence of language on vocal characteristics of speech
2. The results will prove beneficial in carrying out experiments in speech perception and production.
3. The knowledge about cross linguistic variations in the measurement of F0 in phonation and speaking would further facilitate our clinical judgments.

Limitations of the Study and Future Directions

The results of the present study cannot be generalized as the sample size was smaller and also owing to stringent inclusion criteria. Hence, similar studies could be carried out with large sample size. Also a comparative study between Indo-Aryan and Dravidian languages could be attempted to understand the diversity across these languages and such results could be benefitting a multi-cultural society such as, India. Further, the influence of gender across the language group could be compared and contrasted for various acoustic measures.

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