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Original Research Article

A comparative study of phonetogram parameters among female trained Hindustani classical singers, untrained singers and non-singers

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ABSTRACT

Background: Vocal sound is based on the complex yet co-ordinated interaction of phonatory system, resonatory system and respiratory system. Phonetography is a practicable and readily accessible method to investigate and map the quantitative potentialities of vocal output. The objectives of the present study were to determine the phonetogram of trained (Hindustani classical) singers, untrained singer sand non-singers elicited from singing as well as speech task to see if statistically significant differences were present which may indicate an effect of training.
Methods: 90 female subjects between the ages 20-45 (mean age 34.2 years for trained subjects, 26.3 years for untrained subjects and 25.8 years for non-singers) divided into three groups each group consisting of 30 subjects. For the singing task, the individuals had to phonate |a| at habitual level by traversing through eight musical scales. In the speech task, the subjects were asked to count from one to twenty in Bengali at habitat level and at Sustainable cohorts of intensity. This was recorded using phonetogram software Dr. Speech (version 4). The parameters considered were fundamental frequency, intensity, semitones and area.
Results: The study revealed that in both tasks singing and non-singing task for all three groups in all the four parameters of phonetogram significant differences were seen (p=0.000) at 95% level of confidence.
Conclusions: The present study depicted the phonetographic profile of a genre of trained singers and tracked out the parameters on which differences are pronounced between a trained and untrained singer and non-singer.

Keywords: Phonetogram, Training, Singer, Voice profile range, Speech range profile

INTRODUCTION

The voice is an extraordinary human instrument. Spoken language thus contains distinct types of communication as the words themselves and vocal paralanguage. Human phonation is linked to much more than the intellectual act of speech. It serves as a window to each individual providing a passage for spoken verbatim and songs thereby reflecting our emotional state.

The physiology of voice production is extremely complex. The role of neuromotor area consists in origination of vocalisation in the cerebral cortex and then a relay of information via precentral gyrus, motor cortex, motor nuclei of brain and spinal cord. From neural level, the commands are transferred to the larynx, thorax and vocal tract articulators.

Vocal efficiency measures can quantify how well the larynx is functioning in energy conversion, but the ease, fluency, or coordination of the spinning voice may not be captured by these measures.[1] The focus of most singing voice research has been on the classically trained singing voice. Training may be defined by "should include career counselling, education in vocal hygiene, rigorous development of good vocal technique, and accurate

description of voice mechanics".[2] However, the term trained singer, untrained and non-singer are not bound by a set of precisely well-defined criteria. Many authors have variously defined trained singers over the years, ranging from 2 years of formal voice training to 13 years average experience.[3-8] Indian classical music is principally based on melody, rhythm, and not harmony, as is the case in western classical music. Indian classical music is predominantly of two types i.e., Carnatic music and Hindustani classical music. One belongs to the south and the other to the north India respectively.

Several softwares are available to measure the voice and its parameters however, when it comes to music and singer's measurement of dynamic range becomes primary. This is where the role of phonetogram comes into play regarding the measurement of the dynamic ranges of an individual's voice. The phonetogram is a display of acoustic voice parameters in a diagram, which has fundamental frequency on the horizontal axis and vocal intensity on the vertical axis. Phonetogram was suggested to be useful for visual feedback and documentation of changes in voice therapy.[9]

Voice range profile (VRP) is the term that was adopted by the international association of legopedics and phoniatrics in 1992. Multiple references to the VRP were already in use such as the "phonetogram," "phonogram", "voice area" and "voice profile" is few of the terms encountered in the literature. This normally constitutes an oblique shaped area.

Phonetogram manifests itself in two ways as manual phonetogram and automatic phonetogram.

Need of the study

Researches in India focusing on analysis between singers and non-singers have been primordially carried out based on acoustic measures and spectrographic characteristics hence, a study was needed which analyses voice characteristics based on voice range and speech range profiles (SRP). Study that are present in Indian scenario are predominantly based on the Carnatic style of classical singing hence this study differs from others being on Hindustani classical singers. There is a paucity of research on classical singing in western as well as in Indian scenario based on phonetogram parameters. There are limited researches based on the classical singing that encompasses the phonetogram parameters in Indian musical scenario. In lieu of the aspect of speech science, voice range profile should be taken up to understand the vocal dynamics of the singers involved in such a wide range of Indian musical diaspora this what this study aims to do.

Objectives

The objective of the present study were to see the amount of variability that may be brought about by training on voice through the phonetogram parameters amongst female trained (Hindustani classical) singers, untrained singers and non-singers, to investigate the features of the phonetogram in singing and non-singing tasks amongst three groups of subjects in the four parameters which were frequency, intensity, semitone and area enclosed and to compare the results across three groups of subjects for presence of any statistically significant differences between the three. Lastly using this data conclude whether there is any influence of vocal training on the general speech patterns, voice characteristics in both singing and non-singing voice.

METHODS

Study design

A comparative and ex-post facto design.

Study place and period

Measurements were taken in the speech science lab in Ali Yavar Jung National Institue for speech and hearing disabilities, regional centre, Kolkata from September 2017 to October 2018.

Participants

A total number of 90 Bengali female subjects have been categorised equally into three groups. Group 1 trained singers with training in Hindustani classical music for minimum of 10 years. Group 2 consisted of 30 untrained. Lastly, group 3 consisted of 30 subjects who were not exposed to formal or informal vocal training and did not sing on a regular basis.

Selection criteria of patients

All the subjects were included after considering the following points that they did not have any chronic medical problems for the last 3 months, any history of voice problems for the last 3 months. The subjects were screened for structural changes with stroboscopy by E.N.T surgeon as well as for orofacial normalcy, hearing and speech language disabilities, were not taking any medication that may affect the voice and they did not have any respiratory tract infections on the day of data collection.

Instrumentation

The following instruments were used in the study as Dr. Speech Phonetogram version 4 (Tiger DRS Inc., 1998) was used for registering the phonetogram, an omnidirectional microphone (MAX CM- 903 Electret Condenser microphone) was used for recording and sound pressure level was measured with a sound level meter (RadioShack USA Model no: 33-2055) for calibrating the phonetogram.

Phonetographic recommendations by the union of European phoniatrics (UEP) (Schutte and Seidner, 1983) were followed. The microphone with omnidirectional characteristics was placed at a distance of 30 cm from the speaker. The environmental noise was restricted to 40 dB (A).

Procedure

The subjects were asked to perform two tasks. One singing and non-singing task. The singing tasks were as follows:

The subject was instructed to produce the vowel |a| at their habitual frequency and comfortable loudness level, which was recorded on phonetogram. This was recorded as the reference tone. Initiating from the reference tone the subject was asked to increase the pitch through musical scales until the highest pitch level is reached. The reference tone was played back to the subject. The subject is then asked to produce the reference tone level and then decrease it to the lowest level within comfortable limit without whispering. Subsequently from this lowest level, the subject was asked to proceed to the highest pitch through musical tones.

The reference tone is played again to the subject and the subject is instructed to match to the reference tone and asked to produce it to the highest pitch and loudness level.

Non-singing task

The non-singing task was similar to the singing task expect that the participant counts in Bengali from 1 to 20.

Instruction

The instruction given to the client is "please produce the vowel |a| or count from 1 to 20 at comfortable loudness level". Then repeat the same activity twice once from this level to the highest loudness level and then from the comfortable level to lowest loudness level without whispering and lastly from this level to the highest level."

Statistical analysis

The collected data had the following eight metrics extracted which were fundamental frequency with maximum (max F0), minimum (min F0), range (F0 range); sound pressure level with maximum (max SPL), minimum (min SPL), range (SPL range); semitone and area enclosed by phonetogram.

The data was analysed using SPSS version 17.0 statistical software. The data was analysed using measures of central tendency (arithmetic mean) and standard deviation, one-way analysis of variance (one-way ANOVA), independent t-test, and post hoc analysis.

Ethical approval

Informed written consent was obtained from all patients included in the study. Along with this approval was obtained from the institute where the study was carried out. The topic was presented along with the procedure infront of an ethical committee following whose approval the study was commenced.

RESULTS

The data was analysed by categorization of the eight factors in two categories i.e., parameters of voice range profile and speech range profile with four parameters under each.

Frequency

The first factor studied was fundamental frequency. The findings have been tabulated.

Significant differences were found across all three groups on performing one- way ANOVA. Similarly, for multiple comparison the data when compared using LSD post hoc analysis and independent t test between the three groups showed significant differences at the level p=0.000.

Table 1: Mean values for frequency parameters of voice range profile and speech range profile.

Parameter	Group	Mean (±VRP)	Mean (±SRP)	P value
F0 range	1	799.833 (±24.43)	259.933 (±12.97)	0.000
	2	488.266 (±39.29)	170.300 (±18.22)	
	3	152.033 (±19.89)	88.900 (±13.03)	
F0 max	1	944.500 (±25.46)	401.566 (±17.88)	0.000
	2	682.666 (±39.56)	358.433 (±21.76)	
	3	386.566 (±26.10)	315.566 (±21.00)	
F0 Min	1	144.666 (±14.80)	141.433 (±14.72)	0.000
	2	194.433 (±14.30)	188.133 (±12.30)	
	3	235.633 (±13.88)	226.666 (±14.32)	

Table 2: Mean values for speech range profile and voice range profile of vocal intensity.

Parameter	Group	Mean (±VRP)	Mean (±SRP)	P value
SPL range	1	50.89 (±2.9)	41.88 (±1.9)	0.000
	2	34.98 (±1.3)	27.32 (±1.3)	
	3	19.10 (±1.9)	19.17 (±1.5)	
SPL max	1	100.12 (±2.9)	90.87 (±1.5)	0.000
	2	89.59 (±1.25)	82.04 (±1.2)	
	3	80.18 (±2.2)	76.26 (±1.1)	
SPL Min	1	49.23 (±1.1)	49.25 (±2.4)	0.000
	2	54.52 (±1.1)	54.74 (±0.7)	
	3	61.54 (±1.79)	57.13 (±1.0)	

Vocal intensity (sound pressure level)

The next parameter analysed is vocal intensity (sound pressure level). The mean values for the same have been tabulated.

The data when analysed using one way ANOVA showed that all three parameters of intensity at $p<0.05$ level of significance there is at least one inequality of means amongst the three groups. For multiple comparisons between the three groups, using LSD post hoc analysis and independent t test both of which showed significant difference amongst all the three groups.

Semitones

The semitones were analysed for the three groups. The mean values for semitones have been tabulated.

Table 3: Mean values for speech range profile and voice range profile for semitone.

Group	Mean (±VRP)	Mean (±SRP)	P value
1	32.5 (±1.7)	18.0 (±1.3)	0.000
2	21.8 (±1.37)	11.3 (±1.1)	
3	8.9 (±0.84)	5.8 (±1.0)	

Table 4: Mean values for speech range profile and voice range profile for area enclosed by phonetogram.

Group	Mean (±VRP)	Mean (±SRP)	P value
1	663.81 (±27.6)	298.03 (±11.9)	0.000
2	427.72 (±35.3)	176.30 (±8.7)	
3	150.01 (±19.9)	111.02 (±10.2)	

The study revealed significant differences for all three groups and between the three groups when analysed using the above mentioned statistical procedures. Trained singers exceed the other two groups in frequency range, and this could account for the increase of semitone.

Area enclosed by phonetogram

The mean values for area enclosed have been tabulated.

The data showed significant differences in all three groups and between the three groups using all the three statistical methods.

Hence, the study clearly reveals that phonetogram parameters vary significantly between the three groups' i.e., trained Hindustani classical singers, non-trained singers and non-singers in both speech and singing tasks, which may indicate that training has an effect on the outcomes of voice measurements. These differences can be attributed to greater natural capacities in trained subjects or a superior learned control over the voice mechanism. The anatomical differences in the larynx may account for variable vocal capacities in individuals.

DISCUSSION

The aim of the present study were to investigate the features of the phonetogram in singing and non-singing tasks amongst three groups i.e., trained (Hindustani classical) singers, non- trained singers and non-singers, to compare these features amongst the three groups and to explore the effect of training on speech and singing voice. The 4 parameters which were considered were frequency range, vocal intensity, semitones and area enclosed by phonetogram. The study involved 90 Bengali female subjects between the ages 20 to 45 years were included in the study and were categorised into three groups. Group 1 consisting of trained singers with 30 subjects, between 31 to 37 years of age mean age 34.2 years (±3.04) with training in Hindustani classical music for minimum of 10 years. Group 2 consisted of 30 untrained singers, between 25 to 28 years of age mean age 26.3 yrs. (±1.36) i.e. singers who practised singing of folk or film music but did not have any training. Lastly, Group 3 consisted of 30 subjects between 22 to 29 years mean age 25.8 years (±3.39) who were not exposed to formal or informal vocal training and did not sing on a regular basis.

Each of these parameters showed presence of significant differences in all of its sub-parameters amongst all three groups when compared with each other. Other previous literatures have also reported similar findings in these aspects.

Such as in the frequency parameter, the study showed that in all the four parameters to have significant differences. Voice range profile and speech range profile displays an existence of significant differences in terms of fundamental frequency range along with maximum and minimal boundaries. Speech and singing tasks displayed trained singers to have a greater frequency range and greater minimum frequency followed by non-trained singers and non-singers. Reverse hierarchical trends were found for minimum frequency values in both activities. The findings are in agreement with previously established literature. Sulter et al found that frequency range in female-trained singers exceeded non-trained singers at both ends.[10] As was reported by the Awan whereby he concluded that a significant main effect of training, mean values of maximum frequency were also reported to be greater than untrained singers.[4] Thus, it can be concluded that trained singers possess greater vocal dynamics and exceeds the limits of phonational frequency range compared to untrained singers. Similarly, untrained singers demonstrated greater configuration when compared to non-singers. This supports the hypothesis that fundamental frequency between the three groups has significant differences.

Much like the frequency parameter the intensity parameter also showed similar results. The intensity parameter showed consistent higher values of intensity range in trained singers engaged at both types of task followed by untrained and non-singers. Trained singer shave greater maximum SPL and intensity range followed by trained and non-trained singers. However, a reversal of hierarchy is for minimum intensity. This finding was seen for both speech and singing task. Akerlund et al compared phonetograms of female singers and non-singers using the rescaling method.[11] The singers displayed an ability to phonate at slightly lower intensities almost over the entire frequency range; this is in co-relation with the findings of the present study. Awan also found a similar significant difference in trained and untrained singers max SPL. He reported that trained subjects produced a significantly greater mean maximum SPL than did the untrained subjects. In addition, maximum, comfortable and minimum SPL's increase at greater rates across FLs for the trained subjects than the untrained subjects.[4]

However Sulter et al reported that trained subjects and are able to phonate more softly at 30%, 40%, 50% frequency levels than untrained subjects. For louder intensities, trained subjects were able to phonate greater intensities than the untrained subjects.[10]

Trained singers exceeded their counterparts in frequency range and since magnitude of the semitones are considered to be directly proportional to the difference between two minimal quadrants of frequency so it can conclude with increase of dynamic frequency ranges, increase of semitones can be accounted for. Singing and speech tasks for these reveal an increase in semitones according to the level of training amongst the groups. Akerlund et al depicted female singers to have a greater average range.[3] Awan emphasized trained singers to have a greater frequency in terms of both frequency scale and semitone scale.[12] In a study by Chattopadhyay et al, Rabindra sangeet singers were studied where greater values were found in trained singers.[13] Trained singers had a significantly greater phonatory range than non-singers did 38.4 and 29.1 semitones respectively.[11]

The phonetogram area is greater in trained singers followed by non-trained and non-singers in both VRP and SRP has been found in the present study. Phonetogram area is greater in trained singers followed by their untrained counterparts and non-singers. This hierarchical pattern was evident amongst groups for both voice range as well as speech range profile. These findings are similar to many other previous studies. According to Sulter at al lack of quantitative knowledge about what constitutes a normal area results in qualitative with an imaginary frame of reference. As the width between the upper and lower contour increases, the area becomes wide.[14] According to Gramming et al wider the area, the more flexible the voice. In that, both the dynamic intensity and pitch ranges are large.[14] Sulter et al found a significant increase in area enclosed by the phonetogram after voice training.[15] This is in covenant with finding by Awan i.e., trained vocal groups have larger overall vocal areas.[4] Sulter et al found that trained singers had a larger area enclosed by phonetogram than untrained singers when studying Dutch male and female subjects.[10]

Results of this study indicate differences between trained and untrained phonetograms. These differences may be attributed to greater natural capacities in trained subjects or a superior learned control over the voice mechanism. The anatomical constitution of the larynx accounts for variable vocal capacities among persons.

Various authors have described the increased respiratory lung capacity of trained singers, as well as increased lung and rib cage volume and use of different respiratory postures that would increase expiratory force.[17-19]

CONCLUSION

In the present study, the phonetogram has been shown to provide a great wealth of F_O, SPL, semitone and area enclosed information. This information was able to distinguish between vocally trained and untrained groups and non-singers, whereas these groups have often been shown to be indistinguishable in terms of these 4 parameters in the past. The phonetogram also provides characteristic profiles for the groups compared in this study. From these results, it appears that the phonetogram would be ideal for revealing the vocal characteristics of both normal and disordered vocal populations. This technique might be useful in plotting vocal change within these populations as vocal training, therapy, etc., progresses.

Future studies may apply the phonetogram to other populations, as well as attempt to add other types of vocal information to this already informative technique of vocal assessment.

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