

# A Comparative Study among Trained Hindustani Classical Singers, Untrained Singers and Non-singers through Cepstral Analysis

Sujata Mulia<sup>1</sup>, Indranil Chatterjee<sup>2</sup>, Sujoy K Makar<sup>3</sup>, Vijaya Sinha<sup>4</sup>

## ABSTRACT

**Aim:** The present study had the aim to obtain the cepstral measure [Cepstral peak (CP), Cepstral peak prominence (CPP), Cepstral peak prominence smoothed (CPPS)] of trained singers, untrained singers, and non-singers for the sustained vowel /a/, oral passage reading, and singing of the national anthem.

**Materials and methods:** A total of 180 normal-speaking adults within the age range of 20–45 years were considered for the study, and they were divided into three groups: trained Hindustani classical singers (30 males and 30 females), untrained singers (30 males and 30 females), non-singers (30 males and 30 females). The subjects were screened for speech, language, and hearing defects or any other abnormalities. They were asked to undergo three tasks: sustained vowel /a/, oral passage reading, and singing task. Recordings were done, and then acoustic (cepstral) analyses were done through PRAAT software. Statistical analyses were done for the analyzed data. Statistical Package for Social Sciences (SPSS), version 16.0 was used.

**Results:** Significant differences were obtained at  $p < 0.05$  between the genders (male and female) for different tasks and different cepstral parameters. Trained singers were found to have greater means than untrained singers and non-singers. Female participants were found to have a greater mean than the male participants. Significant differences were obtained for CPPS measures in sustained vowel tasks. For oral passage reading, trained singers and non-singers have significant differences for CP measure, no significant difference between trained singers, untrained singers, and non-singers were observed for CPP, and significant differences between non-singers and untrained singers, trained singers and untrained singers were found for CPPS measure.

**Conclusion:** From the present study, it can be concluded that the Hindustani classical trained singers have better harmonic organization and periodicity in their voices when compared with untrained singers and non-singers.

**Clinical significance:** This study provides an insight into the acoustical measure through cepstral analysis of Hindustani classical trained singers when compared to untrained singers and non-singers, which will provide a base for the disordered singing population.

**Keywords:** Cepstrum, Hindustani classical singers, PRAAT, Singing.

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## INTRODUCTION

Voice is defined as the laryngeal modulation of the pulmonary air stream, which is modified by vocal tract configuration.<sup>1</sup> Human voice is extraordinary and is capable of conveying not only complex thoughts but also subtle emotions.<sup>2</sup> Every time we speak, our voice reveals our gender, age, geographic background, level of education, native birth, emotional state, and our relationship with the person spoken to. All these clues (and many more) are contained within small fragments of speech, and other people can “read” our voices with remarkable accuracy.

The human voice explores the power and importance of a uniquely human instrument. When we speak, we use words, but we also “perform” these words using the range and subtlety of our voices. Spoken language, therefore, contains two distinct types of communication: (1) “text” (the words themselves) and (2) “vocal” paralinguistic, the thousands of ways in which any given word can be said. Text is whatever can be typed on a page. Vocal paralinguistic is everything else—intonation, pitch, regional accent, sarcasm, hesitation, truthfulness, emotion, etc.<sup>3</sup> Voice changes throughout life as people change physiologically, intellectually, and emotionally.

Production of voice at the level of vocal folds involves a three-step process:

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- Movement of air pressure toward the vocal folds by the coordinated action of the diaphragm, abdominal muscle, and chest muscles.
- The genesis of a sequence of vibratory cycles by vocal fold vibration. The vibratory sequence of vocal folds is said to be

attributed to the Bernoulli effect. The cycle initiates with the buildup of subglottic pressure and the opening of the inferior part of the adducted folds. Gradually the superior parts of adducted vocal folds are opened by the upward movement of air column. The low pressure created behind the rapid movement of the air column causes the inferior part of the vocal folds to close, followed by the superior part, thereby resulting in the generation of the laryngeal tone.

- The laryngeal tone generated at the level of vocal folds is modified by the vocal tract resonators, preferably by the nasal oral and pharyngeal cavities, and amplifies and modifies the sound allowing the tone to take on the distinctive qualities of voice.

### Phonatory System and its Role in the Production of Voice

Phonation results from the vibration of vocal folds within the larynx. The larynx is the principal structure for producing a vibrating air stream, and the vocal folds, which are part of the larynx, constitute the vibrating elements. The vocal folds vibrate as air pass through them. Rapid opening and closing of the vocal folds periodically interrupt the air stream to produce a vocal or glottal tone within the pharyngeal, oral, and nasal cavities. Modifications and configurations of the vocal tract transform the relatively undifferentiated glottal tone into meaningful speech sounds.

### Singing Voice

Singing is defined as a sensory-motor phenomenon that requires particular balanced physical skills such as respiration, phonation, resonance, and articulation.<sup>4</sup> "Singing should have its existence since speaking was known to mankind."<sup>5</sup> "Singing is specialization over speech."<sup>6</sup> Throughout the ages and civilizations, singing has been heralded as a mode equivalent to offerings to God, as we can see its representations in the form of hymns, *bhajans*, and Sufi songs across the major religions of the world. Singing is a unique way of communicating one's ideas. Singers can also learn to project sound in certain ways, thereby resulting in better resonance within their vocal tract by the use of vocal resonance and also by varying the production is the function of the larynx, which people can manipulate in different ways to produce different sounds. These different kinds of laryngeal functions are described as different kinds of vocal registers. The singing voice justifies a classification because of its notable extension and the vocal texture.

Vocal registers are perceptually distinct regions of vocal quality that can be maintained over some ranges of pitch and loudness. The singer can choose to change the timbre of the spectral quality of the sound without changing pitch. The position of the larynx changes more in natural singers during the transition from one series to another in well-trained singers.

Acoustic analyses have been recommended as standard components of voice assessment in clinical populations.<sup>7</sup> The most frequently used acoustic measurements that relate to vocal quality disruptions include jitter, shimmer, and harmonics-to-noise ratio (HNR).

Although acoustic analyses provide objective measures of voice quality, many of these acoustic measures have substantial limitations. Namely, most traditional acoustic measures of voice quality, such as noise-to-harmonic ratio (or HNR) and time-based perturbation measures (such as jitter and shimmer), are typically only valid when analyzing sustained phonation.<sup>8</sup>

### PRAAT

PRAAT is most often used with speech sounds, in which case the pitch contour is associated with the vibration of the vocal folds, and the formant contours are associated with resonances in the vocal tract. But the use of PRAAT is certainly not limited to speech sounds: musicians and bioacousticians use it for the analysis of sounds produced by flutes, drums, crickets, or whales, and the interpretation of the three analyses will change accordingly.<sup>9</sup>

One of the popular software packages for obtaining cepstral measures is PRAAT. It is a computer program for analyzing, synthesizing, and manipulating speech. It was developed in 1992 by Paul Boersma and David Weenink at the Institute of Phonetic Sciences of the University of Amsterdam.

### Cepstral Analysis

The term "cepstrum" was first coined from "spectrum" along with similarly derived terms such as "quefrency," "saphe," and "harmonics" (from frequency, phase, and harmonics).<sup>10</sup> This is normally defined as the power spectrum of the logarithm of the power spectrum. However, the term cepstrum may also be applied to the amplitude spectrum (square root of the power spectrum), and this will be distinguished by having the unit dB, and the parameters which are used to measure the cepstrum are CP, CPP, CPPS wherein CPP is a measure of periodicity, and it also predicts the roughness.<sup>11</sup> The dominant harmonic is called the CP, which is identified between the minimally and maximally expected fundamental periods. A regression line is fit to the cepstrum to represent the relationship and is incorporated into much multivariate acoustic analysis tools.<sup>12</sup>

## MATERIALS AND METHODS

- Research design: Comparative *ex post facto* research.
- Subjects: A total of 180 Bengali-speaking subjects aged 20–45 years (mean age = 24.7 years and SD =  $\pm 4.9$ ) were considered for the study. These subjects were further categorized into three groups:
  - Group I: Trained singers, which consisted of 60 trained singers with mean age = 25.4 years and SD =  $\pm 5.5$ , both males (N = 30) with mean age = 25.2 years and SD =  $\pm 4.78$  and females (N = 30) with mean age = 25.7 years and SD =  $\pm 6.3$  were included for the study.
  - Group II: Untrained singers consisted of 60 subjects (mean age = 23.7 years, SD =  $\pm 3.9$ ) both males (N = 30) with mean age = 23.8 years and SD =  $\pm 3.87$  and females (N = 30) with mean age = 23.5 years, SD =  $\pm 3.98$  were included in the study.
  - Group III: Non-singers consisted of 60 subjects (mean age = 25.1 years, SD =  $\pm 5.2$ ) both males (N = 30) with mean age = 26.6 years and SD =  $\pm 6.06$  and females (N = 30) with mean age = 23.7 years, SD =  $\pm 3.85$  years were included in the study.
- Inclusion criteria: The following criteria were determined before the inclusion of the subjects in the study. All the subjects:
  - Trained singers who had undergone formal training in vocal music (Hindustani classical) for a minimum of 5 years of singing experience were included.
  - Untrained singers consisted of subjects who practised singing folklore/film music on a regular basis but did not have any formal vocal training.

- Non-singers consisted of subjects who were not exposed to any formal/informal vocal training and who did not practice any form of singing on a regular basis.
- Exclusion criteria:
  - Female subjects from the influence of the menstrual cycle were excluded through the usage of informal questions.
  - The subjects suffering from chronic medical problems, respiratory diseases, neurological problems, history of smoking (more than 3 per day), or regular consumption of alcohol were excluded.
  - Subjects having voice problems for the last 6 months were excluded.
  - Subjects having respiratory tract infections on the day of assessment were excluded.
  - Subjects with regular medication were excluded.
  - Subjects having a problem with orofacial structures, hearing, and speech-language abilities, a recent history of common cold, and throat infections were excluded.

## Instrumentation

- A 64-bit DELL INSPIRON N5050 laptop with a digital sound recording facility was used for the purpose of recording, tabulating, and analyzing.
- A high fidelity head-mounted electret condenser directional microphone fitted with a 3.5 mm output jack was used for the recording purpose.
- Patchogue Rotary Animal Assisted Therapy software version 5.20 was used for the cepstral analysis measurement.<sup>13</sup>

## Procedure

The study was completed in the following phases:

**Subject selection:** The participants fulfilling the inclusion criteria were selected after informal questioning to rule out the exclusion criteria. For the participants of group I, trained singers were selected from a singing institution with at least 5 years of singing training. Untrained singers, who were not exposed to formal training for vocal music but were involved in casual singing were selected as group II. Non-singers, who were not exposed to formal training for speech and music and were not involved in casual singing were selected as group III.

## Materials

Before taking the recording, a written consent has been taken from the participants.

The material used for the study was: (1) to sustain vowel /a/ as long as possible, (2) an oral passage in Bengali which was transadapted from English to Bengali by Kumar, Chakrabarty, Shailat, Singh (2012) for the reading task, and (3) the national anthem "Jana Gana Mana" for a singing task given to the participant on a printed sheet.

**Instructions:** The subjects were asked to do the following three tasks for which they had to wear the headset and adjust the microphone. They were instructed to start phonating, reading, or singing after being indicated by the researcher.

**Tasks:** Recording was done for three tasks. In the 1st task, the participants were asked to sustain /a/ vowel for as long as possible. For the 2nd task, the participants were asked to read the oral passage from the handout provided. The 3rd task was to sing the national anthem "Jana Gana Mana" at a comfortable pitch and loudness level.

**Recording:** The voice recordings of participants were collected with a high-quality unidirectional microphone in an acoustically treated room with low ambient noise, which was fed into the PRAAT software after being converted into "wav" file. The distance between the microphone and the participant's mouth was 4–6 cm (McAllister & Brandt, 2012). Voice recordings were digitized at a sampling frequency of 44.1 Hz and 16 bits/sample quantization. The sample of each participant was retrieved separately for the purpose of acoustic analysis. The acoustic analysis was carried out to extract the cepstral parameters, namely CP, CPP, and CPPs.

## Acoustic Analysis

**Cepstral analysis:** The three cepstral parameters CP, CPP, and CPPs were obtained from the recorded sample. The samples were prepared in order to get the values of the three parameters. Ten samples of 50 ms, each with more variability in the cepstrum were selected from each of the samples of three groups. Thus a total of 5400 samples ( $180 \times 3 \times 10 = 5400$ ) were obtained from three groups. All the 5400 samples were then store as "wav" file in the PRAAT software.

For Cepstral analysis, each sample was first chosen from the already saved list in the PRAAT software on the laptop. PRAAT object option was selected followed by "analyze periodicity" and subsequently "power cepstrogram." This converted sample was selected for Cepstral analysis. The "Query option" in the PRAAT object was chosen, which gave the value of CPPs parameter. Similarly, for obtaining the value of CP and CPP parameter, PRAAT object was selected followed by selecting the 'Power Cepstrum (Slice)' icon and again selecting the query option.

## Tabulation of Data

The obtained data were tabulated in Microsoft office 2010 Excel data sheet.

## Statistical Methods

Measures of central tendency (arithmetic mean) and dispersion [standard deviation (SD)] were undertaken for each parameter in each group, each parameter with respect to gender irrespective of task and group, and task-specific parameters across the group for both genders.

One-way analysis of variance (ANOVA) test was applied for each of the three parameters amongst the three groups, gender difference of three parameters for each group, to find the significant difference between gender for each parameter across the three groups.

Two ways ANOVA was applied for testing between subject's effects of parameters for specific task.

A *post hoc* analysis of multiple comparisons between each of the three groups using Tukey's Honestly Significant Difference (HSD) method was done to find out the level of significance between the two subsequent groups at a 95% level of confidence.

All statistical analyses were performed using the SPSS version 16.0 statistical software.

## RESULTS

Voiced speech sounds result from the resonant action of the vocal tract on the periodic puffs of air admitted through the vocal cords. For pitch-period determination, the time periodicity of the source signal must be obtained from the observed speech signal. Also, voiced-unvoiced decisions require accurate determination of the presence or absence of such periodic puffs in the source signal. This deceptively

simple problem has been the object of considerable research over the past few decades. The professionally trained singing voice is an acoustic source of great beauty, complexity, and communicative power. The acoustic filter characteristics of the human vocal tract are traditionally described in terms of their peaks, which are known as formants.

The statistical analysis findings were categorized under the following statistical processes to test the six research questions:

- Descriptive statistics was done to explain the mean and SD for the gender of each group, for cepstral parameters, and for the three tasks.
- One-way ANOVA was done to compare CP, CPP, and CPPS values of males and females for trained singers, untrained singers, and non-singers.
- Two-way ANOVA was done to compare between subject's effect for gender, training, and gender and training taken together for sustained vowel, reading task, and singing task.
- Post hoc analysis by Tukey (HSD) was done for multiple comparison tests between the group (trained singer, untrained singer, and non-singer) comparison and between the parameter (CP, CPP, CPPS) comparison to find the significant difference between the three groups namely non-singer, a trained singer, and untrained singer and significant difference in between the three parameters namely CP, CPP, and CPPS.

### Effect of Training in Males and Females with Respect to the Cepstral Parameters

The mean and SD of CP measure for non-singer, trained singer, and untrained singer for male participants are shown in Table 1, in which the mean and SD for the trained singer is 52.079 and  $\pm 3.101$ , respectively which is greater than the means and SD of untrained singers which is 50.903 and  $\pm 3.101$  and non-singers which is 50.171 and  $\pm 3.333$  irrespective of tasks and the total mean and SD of three groups together for CP measure was found to be 51.051 and  $\pm 3.081$ , respectively.

The mean and SD of CPP measure for male non-singer, trained singer, and untrained singer irrespective of task are shown in Table 2, in which the mean score for the trained singer is 7.747, and the SD is  $\pm 1.595$  for the untrained singer is 7.178 and  $\pm 1.428$  and for non-singer is 7.079 and  $\pm 1.640$ , respectively which indicates that the trained singers groups have greater means and SD than the other two groups. The total mean and SD of the three groups for CPP was found to be 7.334 and  $\pm 1.579$ , respectively irrespective of task.

The mean score for the trained singers is 4.382, and the SD is  $\pm 1.307$  for the untrained singer is 4.032 and  $\pm 2.640$  and for non-singers is 1.857 and  $\pm 1.547$ , respectively, which is indicative of greater means for trained singers than other two groups. The total mean and SD for the three groups for CPPS measure was found to be 3.424 and  $\pm 2.217$ , respectively irrespective of tasks. The result of one-way ANOVA of CPPS measured for males of all the three groups irrespective of tasks indicates that there is a significant difference

**Table 1:** Mean and SD of CP measure for non-singer, trained singer, and untrained singer of male participants irrespective of tasks

	Mean	Std. deviation
Non-singer	50.171	$\pm 3.333$
Trained singer	52.079	$\pm 3.101$
Untrained singer	50.903	$\pm 2.469$
Total	51.051	$\pm 3.081$

( $p = .000$ ,  $p < 0.05$ ) between the three groups indicating that the males of the three groups differ in terms of CPPS.

The mean (5.088), as well as the SD ( $\pm 1.486$ ) of the trained singer, is more than the untrained (mean = 4.347 and SD =  $\pm 1.441$ ) and non-singer (mean = 4.427 and SD =  $\pm 1.317$ ) for CPPS irrespective of the task for females for all the tasks taken together indicative of greater means for trained group. The total mean and SD was found to be 4.620 and  $\pm 1.450$ , respectively irrespective of tasks. The one-way ANOVA indicates that there is a significant difference ( $p = 0.001$ ,  $p < 0.05$ ) between the females of the three groups for CPPS irrespective of the task indicating females of the three groups differ in terms of CPPS.

### Effect of Training and Gender with Respect to Cepstral Parameters for Oral Passage Reading

The mean and SD of the CP measure for non-singers, trained singers, and untrained singers across genders for task of oral passage reading is shown in Table 3, which shows a greater mean and SD for trained singers, that is, 52.020 and  $\pm 2.503$  for males and 52.054 and  $\pm 2.416$  for females, respectively. Untrained singer's mean and SD for males are 50.782 and  $\pm 2.419$ , for females it is found to be 51.672 and  $\pm 3.166$ , respectively, and for non-singer males, it was found to be 50.478 and  $\pm 3.264$ , and for females it was found to be 51.110 and  $\pm 2.760$  which indicates that male and female trained singers have greater means and SD than the untrained singers and non-singers. The total mean and SD irrespective of gender for all the three groups for the CP measure was found to be 51.353 and  $\pm 2.803$ , respectively.

### Effect of Training and Gender with Respect to Cepstral Parameters for Singing Task

The mean and SD of the CP measure for non-singers, trained singers, and untrained singers across genders for task of singing shows a greater mean and SD for a trained singer, that is, 53.43 and  $\pm 2.873$  for males and 53.47 and  $\pm 2.161$  for females, respectively. Untrained singer's mean and SD for males are 50.40 and  $\pm 2.621$ , for females it is found to be 52.93 and  $\pm 3.657$ , respectively, and for non-singer males, it was found to be 50.47 and  $\pm 2.488$ , and for females, it was found to be 51.43 and  $\pm 1.612$  which indicates that male and female trained singers have greater means and SD than the untrained singers and non-singers. The total mean and SD irrespective of gender for all the three groups for the CP measure was found to be 52.02 and  $\pm 2.920$ , respectively.

### Better Cepstral (CP, CPP, CPPS) Measure for Sustained Vowel, Oral Passage Reading, and Singing Tasks among the Non-singers, Trained Singers, and Untrained Singers Groups

The mean and SD of CP, CPP, and CPPS irrespective of gender for all the three groups are shown in Table 4. The mean and SD for CP was found to be 50.270 and  $\pm 3.348$ , respectively, for CPP it was found to be 7.196 and  $\pm 1.691$  and CPPS was found to be 3.749 and

**Table 2:** Mean and SD of CPP measure for non-singer, trained singer, and untrained singer irrespective of tasks for male participants

	Mean	Std. deviation
Non-singer	7.079	$\pm 1.640$
Trained singer	7.747	$\pm 1.595$
Untrained singer	7.178	$\pm 1.428$
Total	7.334	$\pm 1.579$

$\pm 1.789$ , respectively and the overall mean and SD was found to be 20.405 and  $\pm 21.319$ , respectively for sustained vowel task.

### Difference of Gender with Respect to Cepstral Measures (CP, CPP, CPPS) for Non-singers, Trained Singers, and Untrained Singers

The mean and SD of male and female non-singers for CP measure are shown in Table 5, which shows the mean and SD of CP measure for males to be 50.171 and  $\pm 3.333$  and females to be 51.012 and  $\pm 3.099$ , respectively for non-singers irrespective of task which indicates that females have greater mean than males. The overall mean and SD was found to be 50.591 and  $\pm 3.237$ , respectively.

The mean and SD of the CPP measure for males are 7.079 and  $\pm 1.640$  and for females 7.503 and  $\pm 1.471$ , respectively for non-singers irrespective of the task, which indicates that females have a greater mean than males. The overall mean and SD was found to be 7.291 and  $\pm 1.568$ , respectively.

The mean and SD of CP measure for males are 52.079 and  $\pm 3.101$ , and for females are 52.245 and  $\pm 2.623$ , respectively for trained singers irrespective of task which indicates that females have a greater mean than males. The overall mean and SD was found to be 52.162 and  $\pm 2.865$ , respectively.

The mean and SD of CPP measures for males are 7.178 and  $\pm 1.428$ , and for females are 8.188 and  $\pm 1.534$ , respectively for untrained singers irrespective of task which indicates that females

have a greater mean than males. The overall mean and SD was found to be 7.648 and  $\pm 1.552$ , respectively.

## DISCUSSION

The impact of the cepstral measure on the trained singers, untrained singers, and non-singer is a primary goal to obtain information about the degree of harmonic organization in a signal. The CP gives the measure of amplitude which corresponds to the fundamental period, normalizing for overall signal amplitude. CPPS is the measure involving the individual spectra before extracting CP and CPP. These measures tend to be more reliable than other measures of periodicity.

In the present study, it is hypothesized that the cepstral measures namely CP, CPP, and CPPS will increase prominently in trained singers compared to untrained singers and non-singers. The singers will differ significantly from untrained singers and non-singers in different tasks scheduled like sustained vowel, oral passage reading, and singing National Anthem. There will be a gender difference for different tasks like a sustained vowel, oral passage reading and singing tasks across the respective groups of trained singers, untrained singers and non-singers. A significant difference had been observed in females for the cepstral parameters (CP, CPP, CPPS) across the three groups irrespective of task. The trained female singers had greater means and SDs than their untrained and non-singing counterparts. These findings were in consonance with that of Balasubramaniam et al., who did a study<sup>14</sup> of cepstral analysis on female Carnatic singers, and the results revealed that there was a significant difference between the means of singers and non-singers, indicating that cepstral parameters (CPP and CPPS) were higher among the singers in comparison with non-singers also the singers had higher means and SD than the non-singers.

The *post hoc* analysis done through Tukey for CP measure of the sustained vowel depicts that the trained singers differ significantly from non-singers, trained singers differ significantly from untrained singers, untrained singers also differ significantly from non-singers, but trained and untrained singers did not have any statistical significance through the mean and SD of trained singers are greater than the untrained groups. This showed that the effect of training has no influence on vowel production CP measure. For singing task, the CP measure values can be predicted where the means and SD for trained singers group is more than that of untrained singers and non-singers, females have greater values of CP measure for singing than that of males in all three groups namely trained singer, untrained singers, and non-singers.

The comparison of task A (sustained vowel), task B (oral passage reading), and task C (singing of National Anthem) for male and female for the three groups namely non-singer, trained singer, and untrained singer for CP measure are shown in Figure 1.

CPP values for the task of singing the National Anthem explain the descriptive statistics showing that the mean and SD of CPP measure for singing task is more for trained singers than the untrained singers and non-singers and females have greater mean and SD as compared to males.

The comparison of task A (sustained vowel), task B (oral passage reading) and task C (singing of National Anthem) for males and females for the three groups namely non-singer, trained singers and untrained singers for CPP measure are shown in Figure 2.

Radish et al., studied the modulations of harmonics differently during phonation and singing in female Carnatic singers and found that there was no significant difference between phonation and

**Table 3:** Mean and SD of CP for non-singers, trained singers, and untrained singers for oral passage reading

Gender	Training	Mean	Std. deviation
Female	Non-singer	51.110	$\pm 2.760$
	Trained singer	52.054	$\pm 2.416$
	Untrained singer	51.672	$\pm 3.166$
	Total	51.612	$\pm 2.793$
Male	Non-singer	50.478	$\pm 3.264$
	Trained singer	52.020	$\pm 2.503$
	Untrained singer	50.782	$\pm 2.419$
	Total	51.093	$\pm 2.805$
Total	Non-singer	50.794	$\pm 3.014$
	Trained singer	52.037	$\pm 2.439$
	Untrained singer	51.227	$\pm 2.829$
	Total	51.353	$\pm 2.803$

**Table 4:** Mean and SD of CP, CPP, and CPPS of sustained vowel task for non-singers, trained singers, and untrained singers irrespective of gender

	Mean	Std. deviation
CP	50.270	$\pm 3.348$
CPP	7.196	$\pm 1.691$
CPPS	3.749	$\pm 1.789$
Total	20.405	$\pm 21.319$

**Table 5:** Mean and SD of male and female non-singers for CP measure

	Mean	Std. deviation
Male	50.171	$\pm 3.333$
Female	51.012	$\pm 3.099$
Total	50.591	$\pm 3.237$

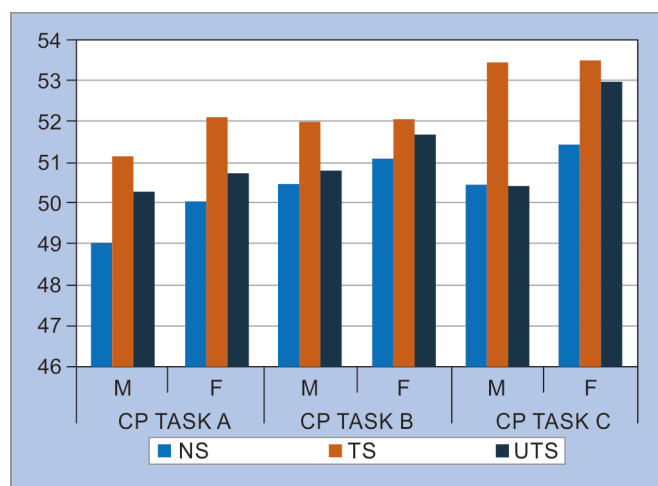


Fig. 1: Comparison of tasks (sustained vowel, oral passage reading, and singing) across the non-singers, trained singers and untrained singers and across the gender (male and female) with respect to CP measure

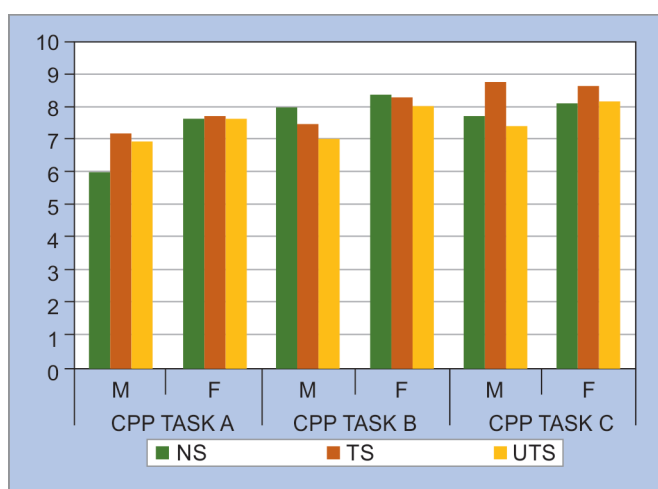


Fig. 2: Comparison of tasks (sustained vowel, oral passage reading and singing) across the non-singers, trained singers and untrained singers and across the gender (male and female) with respect to CPP measure

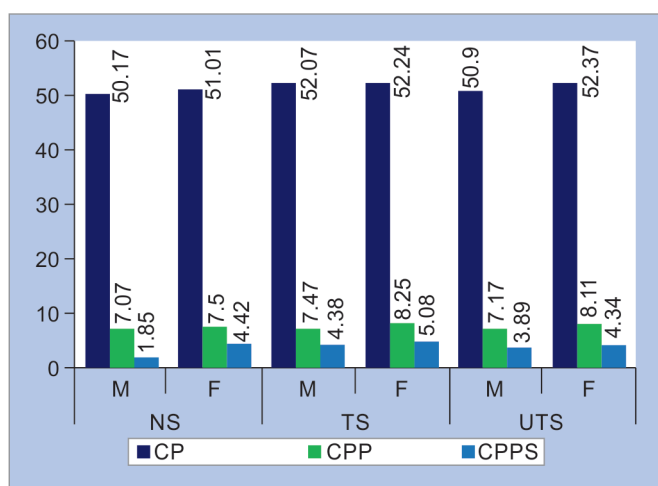


Fig. 3: Gender-wise cepstral parameters across non-singers, trained singers and untrained singers

singing though there was an increased mean score for all cepstral parameters during singing.<sup>15</sup>

The cepstral measures (CP, CPP, and CPPS) for males and females across the three groups, that is, non-singers, trained singers, and untrained singers are shown in Figure 3. In all the groups, the CP measure is highest than the other two measures, namely CPP and CPPS, and females have greater values than males.

## CONCLUSION

The word cepstrum was coined by reversing the first syllable in the word spectrum. The cepstrum exists in a domain referred to as quefrency (reversal of the first syllable in *frequency*), which has units of time. The cepstrum is also widely used in speech processing to deconvolve the periodic voiced excitation signal from the effects of the vocal tract. The cepstrum, defined as the power spectrum of the logarithm of the power spectrum, has a strong peak corresponding to the pitch period of the voiced speech segment being analyze<sup>16</sup>.

Singing is a specialization over speech<sup>17</sup> (Proctor, 1980).<sup>16</sup> Singers modulate their voices in a different way than the normal speaking adults. The attempt of the present study was to find the difference between the Hindustani classical singers with the untrained singers and non-singers through cepstral analysis using PRAAT software. Cepstral analysis was used to accomplish this goal through a performance of different tasks by the participants like sustained vowel /a/, oral passage reading, and singing.<sup>17</sup>

It could be concluded that the trained singers had higher mean and SD scores than untrained and non-singers as the singer's voice is more periodic and harmonic than the other groups. For this, an increase in scores could be attributed to years of regular training and practice.<sup>18</sup> For the singing task, there existed a significant difference between genders as well as training in which the trained singers differed from untrained and non-singers significantly, but the untrained singers and non-singers did not differ significantly for the CP measure. It was found that the CP measure better describes the three tasks of sustained vowel, oral passage reading, and singing task than the other parameters (CPP, CPPS). Within the group, gender differences were not significantly observed for non-singers in CP and CPP, but significant differences were observed in CPPS.

## CLINICAL SIGNIFICANCE

This study provides an insight into the acoustical measure through cepstral analysis of Hindustani classical trained singers when compared to untrained singers and non-singers, which will provide a base for the disordered singing population.

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