

Classifying and Standardizing Parameters of Voice towards Categorizing Individual Variations for Personalised Biomedicine

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Most of the eminent scholars of Unani medicine like Hippocrates, Galen and Avicenna have mentioned about four temperaments on the basis of four types of Humours. They believed that every person has certain characteristic features morphologically, physiologically and psychologically, which are distinct from one another on the basis of dominant humour. The normal proportion of these humours with each other is responsible for health while their imbalance causes disease and it has diagnostic and treatment values. Voice is one of the physiological functions and has been extensively documented in the literature of traditional medicine. Therefore, an adequate dataset of actual voice samples was taken from the random population and it was hypothesized that categorization of people can be done on the bases of their voice characteristics. There is a strong co-relation between voice characteristics and temperament of different individuals, research on voice characteristics was taken to interpret the observations in terms of four temperaments which was not done earlier. The study was carried out on healthy volunteers of the age group between 25–35 years (both the sexes). Zoom recorder was used to record the voice samples and then with the help of PRAAT software a voice report was obtained (shows readings of various voice parameters). Among various parameters in the voice report only eight were chosen according to the need of the study. Then statistical analysis was done to find the differences of individuals on the basis of their voice characteristics. Data suggests that not all voice parameters are equally efficient for categorization; however, rate of speech, pulse, and voice breaks can be used to divide people into four broad categories. The clinical advantage of categorizing voice is discussed with an aim to develop it as a tool for personalized medicine.

Keywords: Alternative medicine, Human categorization, Temperament, Unani, Vocal biomarkers

Introduction

Ancient Greek thinkers believed in the concept of four "humors" that determined personality traits. The four humors and their associated temperaments were:

1. Blood: Excess of blood was linked to a cheerful and optimistic ("sanguine") temperament.
2. Black Bile: Excess of black bile was associated with a depressive and melancholic temperament.
3. Yellow Bile: Excess of yellow bile was believed to cause an angry and irritable ("choleric") temperament.
4. Phlegm: Excess of phlegm was seen as the basis of a calm and composed ("phlegmatic") temperament.^{1,2}

In various classical text books it has been mentioned that the voice characteristics of individuals differs from each other in various ways like voices may be found as soft, clear, dull, high pitched or loud, unclear, harsh, some speaks fast, others are slow and

takes too much time to complete their sentence and many other characteristics.^{3,4} The voice features mentioned in the ancient classical text books of Unani Medicine are mainly based on the observations of physicians of that time where the tools to extract various voice features or parameters of human beings was not as developed as it is today, but it is highly appreciable that their observation was so accurately fine that they used to forecast the diseases, a person may suffer in future on the basis of their voice changes. It shows that the voice was used as one of the diagnostics as well as prognostic tool since long ago.⁵ It also paves a path for researches in this field. Therefore, this study is an attempt to check those parameters of voice using the latest techniques like PRAAT software which can be used for the assessment of the temperament (one of the core concepts of the Unani System of Medicine) of a person for various biomedical purposes. The analysis of the human voice is an important area of study for a

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range of applications in medical as well as engineering sciences. The voice of a human being is known to be a function of the anatomy, physiology, and psychology of the individual.⁶ The voice is a mirror of various aspects of a human being like age, gender and emotions etc., and therefore, the voice in combination with other measurable parameters is important for personalized biomedicine.⁷

Voice is not always produced as speech.⁸ Voice is a unique signature; it reflects the personality, mood, and auditory identity of a person. The uniqueness of speech of any individual is decided by its spectral characteristics.⁴⁻⁷ You can change the way your voice sounds without altering the words you're saying by adjusting the shape of your vocal tract. This can be done by modifying articulation, resonance, and vocal tract length, allowing for different vocal styles and characters. This technique is useful for singers, voice actors, and individuals with speech disorders, as well as in forensic phonetics for speaker identification.^{9,10} If a person wants to communicate with an audience, he must project his voice.¹¹ Knowing how normal voice is produced can help understand voice disorders and disorders where voice may be affected.¹²

The human voice is composed of three key elements:

1. Voiced Sound: The fundamental sound produced by vibrating vocal folds, often described as a "buzzy" sound.¹³
2. Resonance: The amplification and modification of voiced sound by the vocal tract resonators (throat, mouth, and nasal passages), creating a person's unique voice.¹³
3. Articulation: The modification of voiced sound by the vocal tract articulators (tongue, soft palate, and lips), enabling the formation of recognizable words.¹³

Hormones play a significant role in shaping the sound quality of the voice, like:^{14,15}

Sex hormones: Androgens, progesterone, and estrogen directly impact the voice.^{7,13-15}

Thyroid hormones: Also affect voice quality, although the relationship is less straightforward.^{7,13-15}

Laryngeal responsiveness: The larynx is highly sensitive to hormonal fluctuations.¹⁴

These effects vary in accordance to the gender as well:

Effects on Females

1. **Menstrual cycle:** Hormonal changes during the cycle can affect the female voice.

2. **Pubertal development:** The female larynx undergoes changes during puberty.^{14,15}

Effects on Males

I. **Testosterone and Dihydrotestosterone (DHT):** Increased levels during puberty lead to:

- i. Enlarged laryngeal cartilages
- ii. Thicker laryngeal muscles and ligaments
- ii. A drop in voice pitch by about one octave¹⁴

II. **Voice breaking:** The voice may crack or break as the larynx adjusts to hormonal changes.¹⁴⁻¹⁶

These hormonal influences can lead to changes in voice pitch, tone, and quality, making each person's voice unique.

The analysis of the human voice has arisen as an important area of study for its various applications in medical sciences. Various studies have been done on Voice in diseased cases, where it has been used as the biomarker to diagnose neurodegenerative disorders. For example, in Parkinson's disease voice changes are expected to be utilized as an early diagnostic and prognostic biomarkers and to monitor its progress.¹⁷ People with Parkinson's disease often have a rough, shaky, and breathy voice due to muscle weakness and stiffness affecting speech production. This is caused by the disease's impact on vocal cord muscles, articulatory muscles, and overall motor control.^{18,19} The detection of Parkinson's disease using voice is an established biomarker.^{17,18} Parkinson's disease affects speech in various ways, including breathing, voice production, pronunciation, and rhythm.²⁰ Common speech abnormalities in people with Parkinson's include a flat tone, soft or loud voice, unclear articulation, uneven speech rate, hoarseness, and hesitations or interruptions in speech.^{18,21}

Early diagnosis can be made in the cases associated with Dementia by using voice features, as they are simple and non-invasive biomarkers. The observable minor changes in the voice characteristics starts to appear before the major symptoms of the Alzheimer's disease and cognitive impairment and they are helpful in the diagnosis in the early stages.^{17,22} In both the cases voice gets affected. Along with other symptoms it is seen that the rate of speech gets slower and patient hesitates during speaking. Individuals with these conditions may experience language difficulties, including:

1. Word-finding difficulties: Struggling to find the right words, leading to:
 - Circumlocution (describing a word without saying it)

- Filler sounds (e.g., "uh," "um")
 - Indefinite terms (e.g., "thing," "stuff")
2. Disfluencies: Revisions, repetitions, and other speech disruptions
 3. Prosodic changes: Alterations in pitch variation, modulation, and speech rhythm, which can impact emotional expression and responsiveness.¹⁷

As it can be seen that a lot of work has been done on diseased voice but little work is found on healthy voice by using sustained vowels only. In this study in place of vowels, a sentence has been used by keeping the organs of articulation in mind. Also, this study has been performed on healthy individuals to analyse their differences from one another as mentioned in the classical Unani literatures.

Researchers, led by Walia *et al.* created a voice analysis method to distinguish between five groups:

1. Healthy individuals
2. Those with intermittent asthma
3. Those with mild asthma
4. Those with moderate asthma
5. Those with severe asthma

This innovative approach uses voice analysis to identify and categorize asthma severity, offering potential for non-invasive diagnosis and monitoring.²³ Batra *et al.* presented an acoustic analysis of healthy and asthmatic patients voices. Speech was recorded for 25 healthy and asthmatic patients between the age of 40 to 65 years, where it was found that jitter was high for each vowel in case of asthmatic patients and low for healthy persons. Harmonics to Noise Ratio (HNR) was high for healthy people and low for asthmatic ones, only vowel "i" had no changes.^{17,24,25}

Research suggests that physical characteristics, such as weight and body volume, can impact voice production and its acoustic parameters.²⁶ Here are the key findings:

Physical Characteristics' Impact on Voice

1. Body size and voice: Studies show a correlation between body size and voice acoustic parameters.
2. Vocal fold length and biomechanics: The research by Titze *et al.* highlights the importance of vocal fold length, biomechanical stress, and laryngeal muscle activity in determining fundamental frequency (f_0).
3. Body weight and f_0 : Reduced f_0 values are associated with increased body weight.^{10,26,27}
4. Obesity and voice: Obese women tend to have:
 - i. Lower Maximum Phonation Time (MPT)

- ii. Reduced lung capacity due to increased adipose tissue around the ribs and abdomen^{10,15,26}

Physiological Variations

- 1 Individual differences: Despite identical anatomical elements, individuals exhibit distinct physiological characteristics.
- 2 Importance of clinician awareness: Clinicians should consider these relationships between physical characteristics and voice production when assessing and treating voice disorders.^{10,26}

Recent researches done in post COVID time shows that the COVID-19 pandemic has its association with respiratory system and therefore the typical breathing pattern, voice changes (excessively breathy voice), along with the complaints of dry cough, sore throat were observed. These parameters are the primary source of information in context to COVID-19.⁽¹⁷⁾ Distinctive voice patterns can be used to train algorithms that detect COVID-19 and assess its severity, offering a potential non-invasive diagnostic and monitoring tool.^{17,28}

However not much is known about how voice varies in a normal population, but the temperament of a person provides the overall information about the morphology, physiology and psychology. It tells about the anatomical differences, physiological variations and psychological reactions a person which either varies slightly but surely varies from another and that is why temperament is considered as the soul of the biomedicines like Unani system of medicine. As it is the base of health, diseases and the mode of treatments.²

Hypothesis: Based on the above background this study hypothesises that voice can be classified independently as a physiological parameter on its own characteristics alone to assess the human temperaments.

Ethical clearance: The study was performed in a tertiary care hospital in India, under institutional ethical committee approval via order No 215/FUM dated 21/06/2016.

Sample size: A total of 107 volunteers were used for this study.

Inclusion criteria: The volunteers in the age group 18–25 years, non-smokers with no professional training in speaking or singing were chosen for the study. Gender was not taken as a factor for either inclusion or exclusion.

Exclusion criteria: Volunteers below 18 years and above 25 years of age, volunteers with a history of

any voice, or hearing problems, suffering from any ear, nose, throat disorders, speakers with nasal or creaky voice, mentally challenged or having any kind of hormonal imbalance were not included in the study.

Screening measures: Three forms, the consent form, Temperament proforma and Voice intake proforma⁵ were filled by all the 107 random volunteers which were screened as described above.

All volunteers were fully informed about the nature of the experiment and signed a consent form. After the consent of volunteers, pro-forma was filled for the selection of healthy volunteers, detailed clinical history (to rule out any pathological condition) was recorded, and a general examination was done. Volunteers were also questioned about history of tuberculosis, nephropathy, thyroid disorders, or any hormonal disturbances. Then, score based temperament proforma were given to assess their temperament through observational questions and counting their scores. It has not escaped our notice that fear of being interviewed, fear of public speaking and general shyness can change someone's voice even if they had no prior vocal problems. All the factors which can affect the normal voice were taken into the consideration during the screening process.

The sentence which the volunteers were asked to speak was "*Us ped par ek kabootar betha hai. Aao aao thehro thehro wo shakhs ko dekho*". The sentence is in Urdu, which is the predominant language spoken in the region where this study was carried out. The sentence was standardised to include all articulation points.

Material and Methods

All voice samples were recorded using a sophisticated Unidirectional Condenser Microphone (Zoom H5 Handy Recorder). The sampling rate was 44.1 KHz in 16-bit format. No filters were applied to the original voice sample during pre or post processing. The files were saved in .wav format. The volunteers were asked to keep a normal conversational voice and for that a friendly environment was provided to minimize the chances of nervousness among volunteers. The distance between mouth and recorder was kept constant (10 cms) by mounting and fixing the recorder on tripod at suitable height. Each participant was recorded thrice. Voice samples were imported to the laptop where PRAAT was installed to analyse the voice sample.

The collected raw data of voice was imported to excel software to make categories of voice parameters. The categories of individuals were recategorized by the readings of different parameters of voice which were pre categorized by using Temperament proforma (Annexure I), in which score-based questions regarding one's morphology, physiology and psychology were given along with the consent form. It is totally an observational type of proforma prepared in the light of ten parameters given by eminent scholar; Avicenna to assess temperament. It was to cross check the high score on the temperament proforma and to see if they lie in the same temperament group on the basis of voice reading too or not. In the present study digitalization of the same proforma is being tried by using voice as one of the physiological parameters to testify for individual variations from one another. Below are the voice parameters which were taken for the study.

Voice parameters: As the human vocal instrument is comprised of the (a) vibratory body, (b) the respiratory power source and (c) the oropharyngeal resonating chambers. Therefore, voice is characterised by its intensity, frequency and harmonics. The voice sample was analysed for the following parameters:

- 1) **Rate of speech:** Rate of speech is speed of speaking measured in words per minute. It conveys the attitude and emotions of a person. Normally, a person can speak about 125 words per minute and for English speakers in the United States the average speaking rate is about 150 words per minute.^{29,30}
- 2) **Pitch:** Pitch is the comparative highness or lowness of a tone as perceived by the ear. It is the **frequency of vibration** of the vocal folds. This parameter depends on gender and the physiology of the vocal folds.^{12,19,30,31}
- 3) **Pulse (standard deviation of period):** Pulse is repetitive tension of short-duration. It is also used to find out the speech rate of the speaker.^{32,33}
- 4) **Voice breaks:** Voice break is the number of distances between consecutive pulses that are longer than 1.25 divided by the pitch floor.^{1,12,19,30,34,31}
- 5) **Jitter:** Jitter is the small, rapid, cycle-to-cycle changes of period in the fundamental frequency of the voice.^{22,35,36}
- 6) **Shimmer (amplitude perturbation):** Shimmer is similar to jitter, but in this parameter the difference in amplitude from cycle to cycle is measured instead of periodicity as in case of jitter.^{12,19,22,30,31,36}

- 7) **Harmonicity:** Harmonics-to-noise ratio (HNR) and Noise-to-harmonics ratio (NHR) are both measures of the amount of periodic noise compared to the amount of irregular, aperiodic noise in the voice. Since aperiodic noise often represents friction in the vocal tract, so the HNR value is significantly low with hoarse or breathy speech. Similarly in other laryngeal pathologies HNR further gets lowered.^{12,19,30-31}
- 8) **Amplitude (Loudness):** The **amplitude** of the vibrations (i.e., the size of the oscillations of the vocal folds) that affects loudness is called the amplitude. Volume depends on amplitude.^{12,19,30-31}

Results and Discussion

Our hypothesis based preliminary study brought forth the following observations on the basis of statistical analysis (Unpaired ‘t’ test was applied) and graphs drawn with the help of collected data:

1. Participants can largely be divided into four major categories, with the help of proforma and voice characteristics. As the characteristic voice also varies from one individual to another due to the temperamental differences. Therefore, on the basis of the data of various parameters of voice obtained from volunteers, the categories were found exactly in accordance to the concept of four temperaments of Traditional Medicine. They are labelled as category A (Sanguine), B (Bilious), C (Phlegmatic) and D (Melancholic). The categories were according to the readings of voice parameters obtained in different ranges, which are presented in the figures. As it can be seen in the images that in the category D (melancholic) individuals are less in number because it is the temperament which is rare in adult age and common in old age group. As the study was conducted on adult age group their number is less.
2. Of the chosen parameters, three parameters showed a clear-cut differentiation amongst the four categories, these are, rate of speech (Fig. 1), pulse (Fig. 2) and voice breaks (Fig. 3). There are minor changes in the other parameters like pitch, shimmer, Harmonics to Noise Ratio (HNR) etc, and a much larger sample size may show differences more clearly in these parameters as well. It is clearly seen from the graph that few readings of some volunteers in the four categories overlap each other, it indicates that some individuals even in different categories can have similar voices as well but definitely have his/her

characteristic voice by which they can be identified. The volunteers with hot temperament (Sanguine and Bilious) took less time to utter the sentence while the rate of speech of those having Cold temperament (Phlegmatic and Melancholic) is quite slow as they took more time to utter the same sentence. Similarly, the number of pulses and pauses or voice breaks taken to utter the sentence was found higher in cold temperament in comparison to hot temperament. It comes experimentally the same as mentioned in the literature (people of hot temperament speak normally faster, louder, clear than the cold one).

3. The ‘t’ and ‘p’ values of the above three parameters along with their significance are given in the Tables (1, 2 & 3).

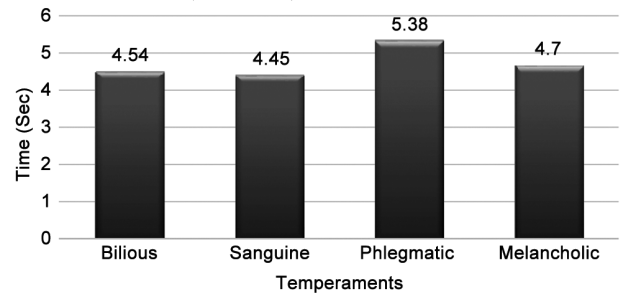


Fig. 1 — Total time taken by the participants of different temperament groups to vocalise the sentence

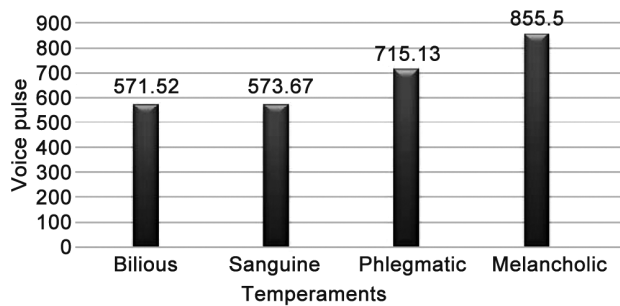


Fig. 2 — Pulse (in number) of the participants in different temperament groups while vocalizing the sentence

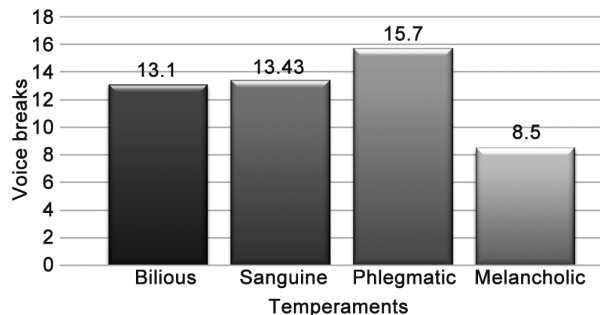


Fig. 3 — Voice break (in number) of the participants in different temperament groups while vocalizing the sentence

Table 1 — Comparative values of ‘Time’ taken by individuals of four temperaments in terms of their ‘t’ and ‘p’ values & significance

Comparison Between	t- value	p- value	Significance
<i>Bilious To Sanguine</i>	0.6680	0.5066	<i>Insignificant</i>
<i>Bilious To Phlegmatic</i>	5.406	0.0001	<i>Highly significant</i>
<i>Bilious To Melancholic</i>	0.8848	0.3817	<i>Insignificant</i>
<i>Sanguine To Phlegmatic</i>	5.560	0.0001	<i>Highly significant</i>
<i>Sanguine To Melancholic</i>	1.133	0.2643	<i>Insignificant</i>
<i>Phlegmatic To Melancholic</i>	2.448	0.0190	<i>Significant</i>

Table 2 — Comparative values of ‘Voice Pulse’ of individuals of four temperaments in terms of their ‘t’ and ‘p’ values & significance

Comparison Between	t- value	p- value	Significance
<i>Bilious To Sanguine</i>	1.756	0.0839	<i>Insignificant</i>
<i>Bilious To Phlegmatic</i>	4.016	0.0002	<i>Highly Significant</i>
<i>Bilious To Melancholic</i>	5.352	0.0001	<i>Highly Significant</i>
<i>Sanguine To Phlegmatic</i>	6.051	0.0001	<i>Highly Significant</i>
<i>Sanguine To Melancholic</i>	7.461	0.0001	<i>Highly Significant</i>
<i>Phlegmatic To Melancholic</i>	2.602	0.0130	<i>Significant</i>

Table 3 — Comparative values of ‘Voice Breaks’ taken by individuals of four temperaments in terms of their ‘t’ and ‘p’ values & significance

Comparison Between	t- value	p- value	Significance
<i>Bilious To Sanguine</i>	0.7257	0.4707	<i>Insignificant</i>
<i>Bilious To Phlegmatic</i>	4.124	0.0001	<i>Highly Significant</i>
<i>Bilious To Melancholic</i>	5.703	0.0001	<i>Highly Significant</i>
<i>Sanguine To Phlegmatic</i>	3.920	0.0002	<i>Highly Significant</i>
<i>Sanguine To Melancholic</i>	7.962	0.0001	<i>Highly Significant</i>
<i>Phlegmatic To Melancholic</i>	6.641	0.0001	<i>Highly Significant</i>

The ‘t’ and ‘p’ values show that the significance is found between hot and cold temperament, as the two hot and two cold temperaments share somewhat similar qualities. Therefore, significant results are found in contrast qualities or temperaments.

Conclusions

Human temperaments play a key role in diagnosis, prognosis and treatment. Human voice characteristics have been mentioned among the ten much known parameters for assessing the temperament called as Ajnas-e-Ashra (ten determinants) in the classical text books of Unani system of Medicine. Almost all the points mentioned in the proforma are theoretical or observational but this study is a step to digitalize the voice parameters for the assessment of the human temperaments. It can be used as a consolidated parameter to categorize the human beings for various biomedical purposes. This study proposes four major categories of people, within the healthy population, which show characteristic parameters of voice. This study suggests voice can be a useful physiological parameter for population categorization and personalized medicine. Expanding the dataset will help refine the results, particularly for parameters

with slight insignificant differences, and potentially reveal more robust patterns and correlations. As medicine progresses to personalised biomedicine and the potential of this study is that the individual variations in voice parameters will come up as a prognostic and diagnostic marker of the diseased state.

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