

# Estimation of Pitch and Fundamental Frequency Variation Between Normal Males, Females and Intersex Population

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## Abstract

Human beings have certain uniqueness in their voices that helps determine their individuality. The most important characteristic of voice is the Pitch. The average vocal range for masculine voice ranges from 90-150 Hz and for feminine voice, it ranges from 190-240 Hz. This pitch is decided by the development of the vocal tract during puberty by the effect of testosterone hormone i.e. Longer the tract, lower the pitch and vice versa. However, for people belonging to the intersex community, the low production of testosterone causes the vocal tract to develop differently than males and females. Because of this reason, their pitch has its own individual range and hoarseness of quality. This study was aimed to evaluate the difference in intersex population voice characteristics as compared to normal adult males and females. It was found that intersex voice has a distinctive Pitch range of 150-190 Hz with the mean frequency being 167 Hz. It was also discovered that due to the peculiar dialect practiced by the intersex community, especially in the western part of the Indian subcontinent, there is a noticeable difference in the time duration for pronouncing various vowels from the time duration taken by males and females to pronounce the same vowels.

**Keywords:** *intersex; pitch; fundamental frequency; forensic*

## Introduction

The sound produced in a person's larynx and uttered through the mouth, as speech or song is known as the 'voice' of that person, as defined by the Oxford Dictionary. Voice has many different measurable characteristics like loudness, pitch and quality.<sup>(11)</sup> The human sound system consists of 3 systems- Respiratory system generate the air pressure that produces sound through the vocal cords. Phonatory system causes the closure and opening of the vocal cords. Sub-glottic air pressure is chiefly responsible for producing sounds by vibrations of the vocal cords. The frequency of vibration of the vocal cords is called fundamental frequency, also known as the Pitch. As the sounds moves through vocal tract, it gets modified into different formant frequencies, based on language, size, illness etc. Articulatory system is responsible for converting sound into speech<sup>(14)</sup>.

Intersex is a condition due to which a person is born with sexual organs that do not classify completely under the definitions of male or female physiology. The adrenal glands are responsible for production of endocrine hormones like testosterone. During puberty this hormone causes the development of secondary sexual characters like facial hairs, pubic hairs and deepening voice. At birth, the vocal tract of males and females are of same length. But due to action of testosterone during growth years, the vocal folds of males increase in length twice the rate of females. However, in intersex people, there is abnormalities in the levels of testosterone produced due to several reasons causing the quality of voice to differ from males and females. These conditions may not be seen at birth but may develop at the onset of puberty due to virility caused by low or none production of sex hormones. The various conditions that cause intersex in a person, as given by Intersex Society of North America<sup>(1)</sup> are:

- Androgen Insensitivity Syndrome (AIS)

This is seen in a genetically male human, due to a genetic anomaly passes from the mother. Due to this

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anomaly, the body does not respond to the androgen hormones like a normal male. Hence, they do not develop male reproductive organs. Their physiology is like that of the external female reproductive system.

- Aphallia

This condition exists when a person is born without a penis and the testicles do not descend. They are otherwise biological male, without being able to function as one.

- Clitoromegaly

This condition is seen due to introduction of unsafe steroids in a pregnant woman causing the female foetus to develop a large clitoris. As they reach adolescence the biological women tend to acquire male characteristics.

- Congenital Adrenal Hyperplasia

This is a type of genetic disorder that affects the adrenal glands. It affects the production of androgens, that regulate the development of primary and secondary sexual characters in a human being. This results in development of ambiguous genitalia in female fetuses. The other symptoms seen are absence of menses, excessive facial and body hairs, and a deepened voice. Excessive production of testosterone affects the overall development of a genetic female.

- Klinefelter Syndrome

This syndrome is seen when a biological male child is born with an extra X chromosome. It causes lower production of testosterone at adulthood. They have lesser facial hairs and enlarged breast tissue. They are mostly sterile.<sup>1</sup>

The effects of these syndromes produce varying results in different individuals. But the underlying insufficiency of testosterone affects the overall development of voice, which is the main focus of this study. While performing any automated speech analysis to determine the culprit, algorithms used generally classify the voices according to pitch and formant frequencies. So, it is of utmost importance that there be an objective range of pitch for all the three genders existing in the society today.

For **literature review**, the researches that were considered showed that mostly subjective tests like questionnaires, rating scales and interviews were used to judge how the subjects themselves, speech

therapists and neutral audience perceived the voice they heard. This raises a lot many questions, regarding the perceived masculinity or femininity of one's voice, irrespective of their physical features or the way they perceive themselves. The subjects underwent a number of procedures such as testosterone treatment, Pitch-raising surgery and Glottoplasty to change the range of Fundamental Frequency of their voice. Although all the researches showed a huge correlation between Pitch and Gender Perception, an objective value of the pitch range of Intersex community was not established.

## Materials and Methodology

### Sample Collection:

In this study, we collected total 300 samples from the Gujarati population. 100 of these samples were from the intersex population, 100 were from the male and 100 from the female population. Consent forms were prepared for collecting information about the subjects with fields about the subjects' mother tongue, place of origin, any habits of oral conditions that might affect the speech sample and finally, a declaration that the samples will not be used for any other purpose other than for the research intended. Since most of the subjects were illiterate and knew little or no English, a standard text could not be used. Instead they were made to give their introduction for a period of 2 minutes. The recording was done in indoor environment making sure that only one speaker was being recorded. All the recordings were done in a standard instrument, namely, Digital Voice Recorder VN-711PC.

### Sample Preparation:

For the purpose of sample preparation, Goldwave software was used. Using this software, the formats were changed from .wma to .wav as Praat software accepts only .wav or .mp3 format for analysis. The samples were then saved as a PCM signed 24 bit mono channel at 11025 Hz sampling rate. If there was noise in any of the samples, it was reduced using this software.

Further 5 samples of each vowel chosen for analysis, was segregated by cutting and pasting into a sub-file of mono channel and 11025 Hz sampling rate from the entire sample. This was used for the final analysis done in Praat software.

### Analysis

- The sample of interest is fed into the software

from the Open→ Open long sound file option in the main window of Praat<sup>(13,15)</sup>.

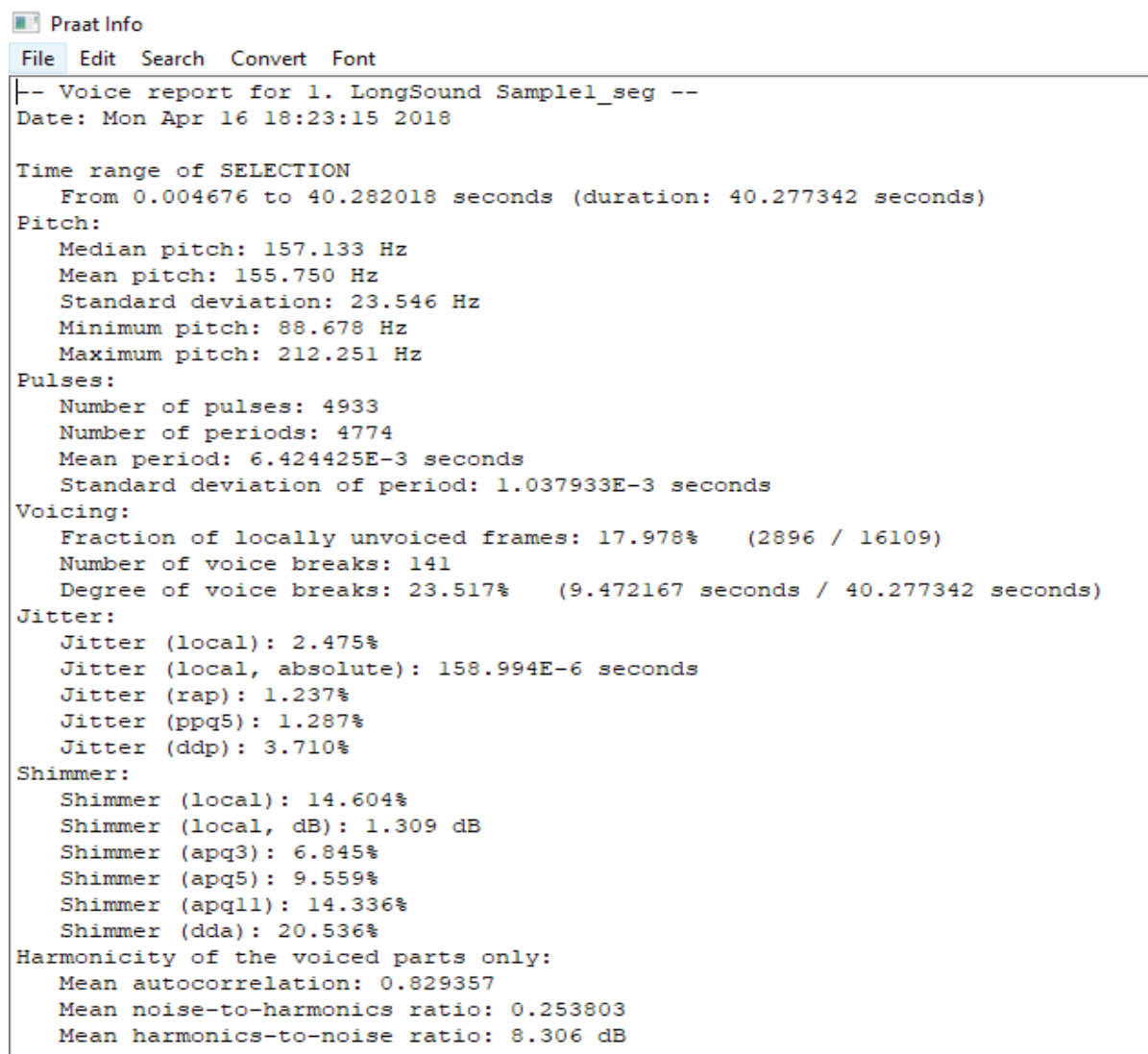
- The sub-window of Praat showing the waveform of speech is opened. It has 2 windows. The top one shows the frequency time graph. The bottom one shows the energy graph and pitch markings.

- The entire sample is heard and the mean pitch of the whole sample is noted ( Figure 1). The words with the chosen vowels are selected and 'sel' option is clicked at the bottom of the screen.

- This magnifies the selected portion of the sample. From this the vowel is selected and time duration notes. The average pitch for that segment is taken as an observation.

- This process is repeated 3 times in the same sample for the same vowel. The chosen vowels are /a/, /e/ and /u/.

- The analysis is done on all the 30 samples of speech. The observations are noted down in Excel worksheets.



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Praat Info
File Edit Search Convert Font
|-- Voice report for 1. LongSound Sample1_seg --
Date: Mon Apr 16 18:23:15 2018

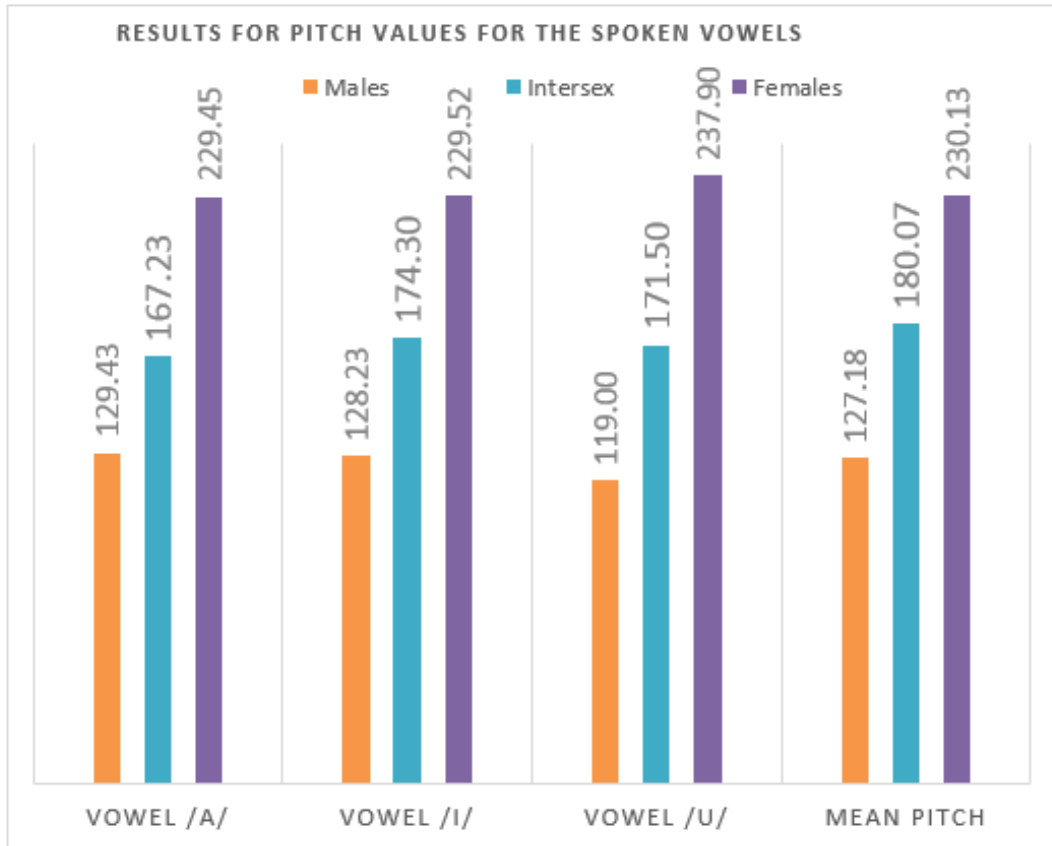
Time range of SELECTION
  From 0.004676 to 40.282018 seconds (duration: 40.277342 seconds)
Pitch:
  Median pitch: 157.133 Hz
  Mean pitch: 155.750 Hz
  Standard deviation: 23.546 Hz
  Minimum pitch: 88.678 Hz
  Maximum pitch: 212.251 Hz
Pulses:
  Number of pulses: 4933
  Number of periods: 4774
  Mean period: 6.424425E-3 seconds
  Standard deviation of period: 1.037933E-3 seconds
Voicing:
  Fraction of locally unvoiced frames: 17.978% (2896 / 16109)
  Number of voice breaks: 141
  Degree of voice breaks: 23.517% (9.472167 seconds / 40.277342 seconds)
Jitter:
  Jitter (local): 2.475%
  Jitter (local, absolute): 158.994E-6 seconds
  Jitter (rap): 1.237%
  Jitter (ppq5): 1.287%
  Jitter (ddp): 3.710%
Shimmer:
  Shimmer (local): 14.604%
  Shimmer (local, dB): 1.309 dB
  Shimmer (apq3): 6.845%
  Shimmer (apq5): 9.559%
  Shimmer (apq11): 14.336%
  Shimmer (dda): 20.536%
Harmonicity of the voiced parts only:
  Mean autocorrelation: 0.829357
  Mean noise-to-harmonics ratio: 0.253803
  Mean harmonics-to-noise ratio: 8.306 dB

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Figure 1: Screenshot of the window that shows information about the entire audio clip

### Findings

#### Observations based on Pitch Frequency among the three groups

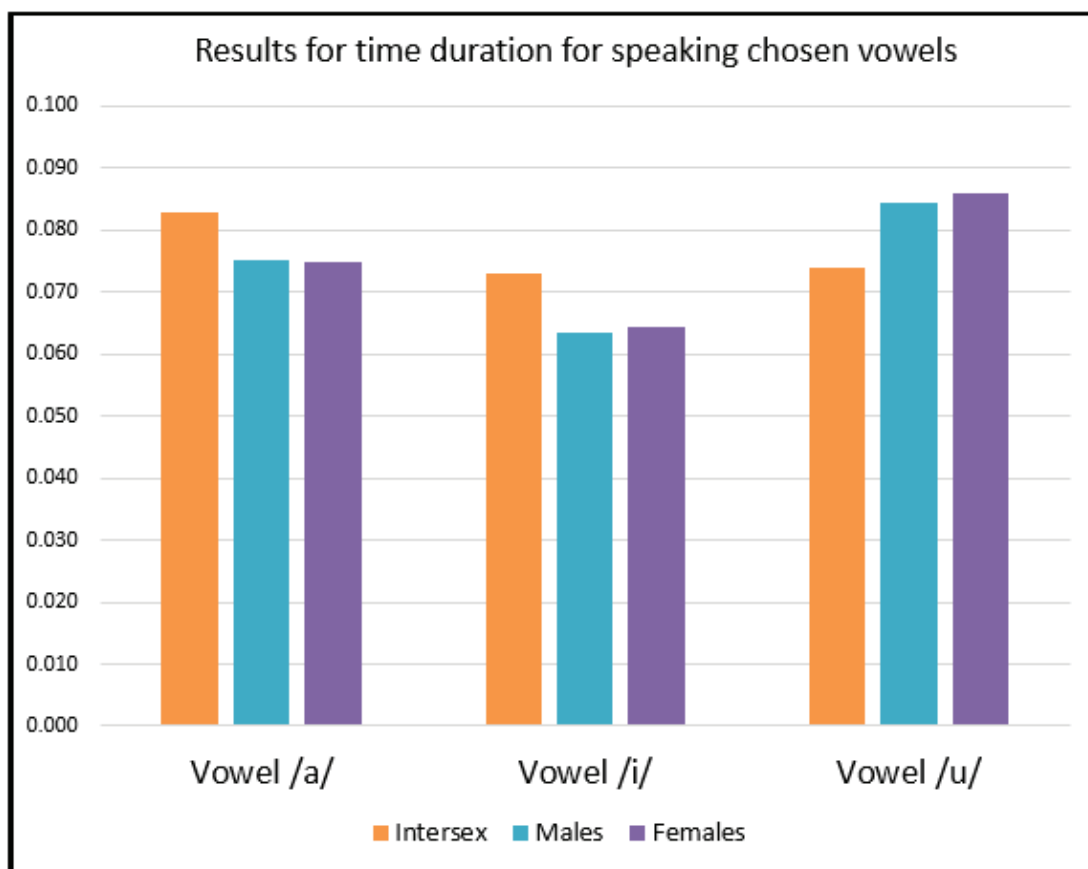


**Graph 1: Bar graph representing the mean pitches of the three groups according to vowels.**

Using the graph above, we can see that there is a clear demarcation of pitch range between males, females and intersex. The intersex pitch range exists between the male and female pitch range, i.e. from 150-190 Hz if seen in a broad sense. This information can be used to further individualize the voice function for the intersex community. Individualisation of pitch values while working with voice samples is a very important tool when it comes to forensic voice analysis as it can help in narrowing down the suspect pool and characterize the voice as male, female or intersex.

#### Observation based observations of time duration for chosen vowels among the three groups

Gender/ Time duration( Seconds)	Vowel /a/	Vowel /i/	Vowel /u/
Intersex	0.083	0.073	0.074
Males	0.075	0.064	0.084
Females	0.075	0.064	0.086



**Graph 2:** Bar graph representing the observations of time durations of the three groups according to vowels

From the above bar graph, we can clearly see that the time duration needed to enunciate the chosen vowels shows more similarities between males and females, than with intersex subjects. This is due to the fact that the intersex community, especially in the western part of India have developed their own unique pattern of intonation of speech. Some words that would otherwise not be dragged as much while speaking in normal dialect by male and female subjects, are pronounced in a distinctive prolonged fashion by the intersex subjects. This is another individualizing characteristic that could be found through this study.

### Conclusion

From this study undertaken using 100 subjects each from the male, female and intersex genders, it was found that the Pitch, also called Fundamental Frequency is unique for each of the genders. The pitch for males and females were known to us due to different studies previously done. The purpose of this study was to find an objective range of Pitch values for the intersex voice. From the results obtained it was seen that intersex

voice lie in the range of 150-190 Hz, whereas male and female voice lies in ranges of 116-133 Hz and 217-255 Hz respectively. This gives us a very individualized characteristic of intersex voice, which can be a topic for further research.

**Conflicts of Interest:** There are no conflicts of interests to be declared

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**Ethical Clearance:** The samples were collected from volunteering participants and a record of their signed consent had been maintained using consent forms.

### References

1. 'What is intersex?' Intersex Society of North America [Internet] 2019 [cited 2019 Aug 8] Available from: <http://isna.org/>
2. Azul D, Nygren U, Södersten M, Neuschaefer-Rube

- C. Transmasculine People's Voice Function: A Review of the Currently Available Evidence. *Journal of Voice*. 2017;31(2):261.e9-261.e23.
3. Gelfer M, Van Dong B. A Preliminary Study on the Use of Vocal Function Exercises to Improve Voice in Male-to-Female Transgender Clients. *Journal of Voice*. 2013;27(3):321-334.
  4. Macquarie University - Acoustic Theory of Speech Production: Source-Filter Theory Speech. Available from: [http://clas.mq.edu.au/speech/acoustics/frequency/source\\_filter.html](http://clas.mq.edu.au/speech/acoustics/frequency/source_filter.html)
  5. Gross M. Pitch-raising surgery in male-to-female transsexuals. *Journal of Voice*. 1999;13(2):246-250.
  6. Hancock A, Colton L, Douglas F. Intonation and Gender Perception: Applications for Transgender Speakers. *Journal of Voice*. 2014;28(2):203-209.
  7. McNeill E, Wilson J, Clark S, Deakin J. Perception of Voice in the Transgender Client. *Journal of Voice*. 2008;22(6):727-733.
  8. Meister J, Hagen R, Shehata-Dieler W, Kühn H, Kraus F, Kleinsasser N. Pitch Elevation in Male-to-female Transgender Persons—the Würzburg Approach. *Journal of Voice*. 2017;31(2):244.e7-244.e15.
  9. Nygren U, Nordenskjöld A, Arver S, Södersten M. Effects on Voice Fundamental Frequency and Satisfaction with Voice in Trans Men during Testosterone Treatment—A Longitudinal Study. *Journal of Voice*. 2016;30(6):766.e23-766.e34.
  10. Re D, O'Connor J, Bennett P, Feinberg D. Preferences for Very Low and Very High Voice Pitch in Humans. *PLoS ONE*. 2012;7(3):e32719.
  11. Deguchi S. Mechanism of and Threshold Biomechanical Conditions for Falsetto Voice Onset. *PLoS ONE*. 2011;6(3):e17503.
  12. Schwarz K, Fontanari A, Costa A, Soll B, da Silva D, de Sá Villas-Bôas A et al. Perceptual-Auditory and Acoustical Analysis of the Voices of Transgender Women. *Journal of Voice*. 2018;32(5):602-608.
  13. Praat: doing Phonetics by Computer [Internet] 2019 [cited 2019 Aug 8] Available from: <http://www.fon.hum.uva.nl/praat/>
  14. The Acoustic Theory of Speech Production. Haskins.yale.edu [Internet] 2019 [cited 2019 Aug 8] Available from: <http://www.haskins.yale.edu/featured/heads/mmsp/acoustic.html>
  15. Using Praat software [Internet] 2019 [cited 2019 Aug 8] Available from: <https://www.ee.iitb.ac.in/student/~daplab/resources/SpeechAnalysisUsingPRAAT.pdf>