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Impact of Female Menstrual Cycle on Voice Production with Special Reference to Wavelet Transform

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Abstract

The main objective of this review is to discuss the impact of female hormonal changes on voice production throughout the whole life cycle of female starting from the puberty continued in reproductive year and then declined at menopause. For this purpose we analyse the voice signals by using the very effective and robust method of wavelet analysis called wavelet transform.

Keywords and Phrases: female hormones and hormonal fluctuation, voice production, female life cycle, voice and wavelet transform.

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1 INTRODUCTION

The previous studies investigated that the fluctuation of hormones around female life cycle affects their psychology, physiology and behavior [15, 12]. Thus, female voice production might also be affected during menstruation just as it is during the follicular and luteal phase [1, 8]. Previous studies have shown that hormonal changes in females across the menstrual cycle period affects vocal production and the documentations in this field indicated the most changes in premenstrual or ovulation period. That showed the impact of menstruation on vocal fold functioning and voice production. Recent studies shows that there is a perceptual difference between voice recordings in different phases of the menstrual cycle. The human voice analysis has been a very

important area of study for it's multiple application in Engineering and Medical Sciences. Basically the voice analysis deals with some special parameters like pitch, intensity, formants, hormone to noise ratio, maximum phonic time etc. obtained by applying desirable techniques on voice signal. In this paper we will discuss the impact of female hormonal changes on vocal production, by using the application of wavelet transform to analyse voice signal. For this purpose let us focus on the following:

1. **Wavelet transform and voice analysis:** To analyse a voice signal a very efficient and robust technique of wavelet analysis is used, which is wavelet transform [25]. Wavelet transform is used to decompose an arbitrary signal into localized contributions labelled by a scaled parameter. In this paper we will discuss the application of wavelet transform which is based on time frequency multi-resolution analysis of wavelets for extracting features of voice signals. After the application of wavelet transform on voice signal, the input signal is decomposed into various frequency components, then one can select an optimal wavelet of specific frequency range. For all the above process online free software are available for the analysis of voice parameters of voice such as intensity, pitch, maximum phonic time (MPT), formants etc. One of them is PRAAT.
2. **Menstrual cycle and voice production:** The normal menstrual cycle or monthly cycle is the process of hormonal changes in female body starting from puberty age of 8 to 12 years, continued in the reproductive years ends at Menopause at the age of 40 to 45 years. The normal menstrual cycle is of length 28 to 35 days in healthy women. It is the regular monthly process involves 4 key hormones, in which two of them are estrogen and progesterone released from ovary while the other two hormone are follicle stimulating hormone (fsh) and luteinizing hormone (LH) released from pituitary gland.

The vocal folds have often been described as hormonal targets ([1, 8]). The behavioural, psychologic and physiologic effects of the menstruation on voice have been researched for more than 40 years; however, the degree of changes on vocal fold vibratory characteristics have not been determined.

2 Observations:

There is very less work done in the field of changes in human voice along with the hormonal fluctuations. The changes in hormone levels effect the larynx and surrounding vocal fold tissues. Puberty, menopause, pre-menstruation, pregnancy, hormone replacement therapy and hormonal contraceptives [1, 8, 3, 6, 9], all involve hormone changes that impact vocal production and⁄or acoustics. Research shows that female hormonal changes in the whole life cycle specially at menstrual cycle period affects vocal production, most work has documented shift at ovulation period (high fertility period) or during pre-menstruation. The recent studies investigated perpetual differences between voice recorded during menstruation with the voice recording taken at other time of menstrual cycle period.

Piptone and Gallup [19] in 2008 utilized four voice recordings for each of the 21 naturally cycling females and showed that rating of voice attractiveness increased in

across menstrual cycle but females using hormonal contraceptive showed no relationship between cycle point and voice attractiveness. This shows that there exists some relationship of voice with menstrual cycle.

In 2012, the same author Piptone and Gallup [19] used the same voice recordings of 21 female undergraduates from the state university of New York at Albany and also some additional female voice recordings for each of the four faces of their full menstrual cycle. All the women were naturally cycling. They were asked to count 1 to 10 in a computer microphone for each of the phone recordings in a full menstrual cycle. Investigated that there is a perceptual difference between voice recorded during menstruation compared with the recordings taken in the other phases of menstrual cycle period and indicates that voice recordings taken at lowest fertility time may uniquely impact the women's voice production. This studies investigated how menstruation affects voice production and perception by male raters. The fluctuation of hormones around menses affects female physiology and behaviour [15, 12]. Thus vocal production might also be affected during menstrual period [1, 8].

Celik, Oner, et al [7] took voice recordings of 16 females who were non users of oral contraceptive for their cross sectional study of the influence of menstrual cycle on speaking and voicing task. Acoustic analysis (pitch intensity, formants harmonic to noise ratio, maximum phonic time s/z ratio jitter and shimmer, harmonic -to-noise ratio etc.) had performed during all phases of menstrual cycle period. A celebration tune of known intensity is recorded for 10 to 15 minutes everyday before each participant and used as a reference for acoustic analysis. the participants were asked to phonate and sustain approximately for 5 seconds at the most comfortable pitch and intensity to the vowel /a/. Acoustic analysis is done by the online available free software Praat.There was no statistically significant difference was found in the parameters (pitch, intensity formants, harmonics to noise ratio MPT) between the phases of the menstrual cycle. On the other hand he found the best perceptual voice in the period with high estrogen level or mild menstrual period compared to the low level and he also found the significantly poor voice quality in the pre menstrual period. The vocal fold mucosa contains specific receptors for sex hormones; therefore, sex hormones, such as estrogen and progesterone, have a great impact on voice by affecting the female vocal fold histology and laryngeal function [21, 20]. Many females either professional or non professional voice users experience changes in voice during pre-menstrual period characterised by vocal fatigue, loss of power and decreased vocal range [22, 20]. Starting approximately 4-5 days before menstruation, pre menstrual voice changes are usually seen in nearly one-third of women [2]. All the above findings may reveal a correlation between hormone levels and histologic changes in the vocal folds, which in turn may effects their viscosity, mass and tension and therefore modify their oscillation property. There was no statistically significant difference in any of the acoustic analysis parameters (F0, intensity, jitter, shimmer and HNR) between the phases ($P > 0.05$). When a comparison was made with regard to MPT and s/z ratio, no statistically significant difference was found between the phases. It was the first study that compares the objective and subjective voice parameters not only during menstrual cycle and also correlates them with plasma levels of estrogen and progesterone. Perpetual assessment of voice, either clinically

evaluated or patient self- evaluated is significantly changed among various phases of menstrual cycle. a limitation of the study is that there is a discrepancy between acoustic analysis on continuous speech samples (significant).

Fischer [10] observed that the fundamental frequency of free speech sample varies marginally significantly in all the faces of the menstrual cycle. The highest value of fundamental frequency found in the preovulatory period and the lowest value was at the ovulation period. F_0 was also found significantly higher in the days prior to ovulation and highest in the beginning of cycle for sustained vowel, dropped somewhat in the ovulatory period and then increased again. For this purpose the recordings were collected by computer microphone and then analysed manually to obtain different results. Fischer [10] also modified the fact that human voice provides rich source of information about individual attributes such as development stability, body size and emotional state. All the facts indicates that female voice characteristic changes across the whole menstrual cycle, and women speaks with higher fundamental frequency in the high fertility compared to the low fertility period. Overall variation throughout the cycle, however, precluded unequivocal identification of the period with the highest conception risk. the analysis of vowel samples revealed a significant increase in degree of unvoiceness and noise to harmonic ratio during menstruation, possibly related to an increase in tissue water content. Bryant and Haselton [5] provided evidences for acoustic variation in relation to cycle stage. They obtained voice recordings from 69 subjects in big-and low-fertility periods as estimated by average cycle length.

In 2017, Pavela Banai [18] used recordings of 44 naturally cycling women and 20 hormonal contraceptive users. These recordings were done in voice proof rooms by keeping the digital microphone at approximately 40 cm from their mouth. During the whole recording session the females were instructed to produce five monophthong vowels (/a/ as in ’bar’, /e/ as in ’let’, /i/ as in ’bee’, /o/ as in ’cold’ and /u/ as in ’you’). Recordings were stored and uncompressed WAV format was used in voice analysis. By the all observations the researcher found higher F_0 min in the late follicular those compared to the menstrual phase and lowest voice intensity in the lutial phase. Naturally cycling women produced a higher minimum pitch compared with hormonal contraceptive users. Furthermore, women in the natural cycle group had higher values of hormonic to noise ratio, but only in the menstrual phase. He investigated changes in sexually dimorphic vocal characteristics and quality of women’s voices in different phases of the cycle and to compare these with users of monophasic hormonal contraception. After analysing the recorded voice sample researcher came to the result that voices of naturally cycling women had higher minimum pitch in the late follicular phase compared with the other phases. In addition, voice intensity was at its lowest in the luteal phase. In contrast, there were no voice changes across the cycle in hormonal contraceptive users. Also they observe higher minimum pitch in the late follicular phase, minimum intensity in the luteal phase and higher harmonic to noise ratio in the menstrual phase.

In 2016 Tatar [23] have selected 69 healthy Turkish women with mean age of 31.5 ± 6.0 years, with normal physical findings and without vocal abuse or dysphonia were participated. Detailed physical and videostroboscopic larynx examination was done.

Participants were asked to record sustained /a/ and /i/ vowels and analysis was done in pre menstrual, menstrual and post menstrual period. The data indicated that during the pre menstruation harmonic to noise ratio, jitter %, shimmer %, were significantly higher than that of the other two periods. Effect of estrogen and progesterone on vocal fold was clearly visible. The researcher also collected the voice sample of 6 women, who wear non-smoking, healthy and no history of voice difficulty of age 20 to 23 years, in lutial, pre menstrual and menstrual phases by a microphone at 30 cm from the mouth. All the women's were no contraceptive users from last 1 year. They found variability in individual participant data, no significant main facts of time of recording, significant main effect of day of recording on F_0, standard fundamental frequency etc.

In 2009, Meurer [16] rerecorded voice samples using a microphone, model 16 A, and a Sony digital tape recorder (MiniDisc MZ- R70-S1; Sony Corporation, Tokyo, Japan), during two menstrual and stored in mini discs. In each cycle, a recording was made between days 5 and 8 and another one between days 18 and 23. The noise level of the recording room was measured by the software used for analyses of the phono-articulatory patterns. The utterance of the prolonged vowel /a/ was recorded to check the fundamental voice frequency (F0), higher frequency (Fhi), lower frequency (Flo), and standard (Fo variation). Five repetitions of the vowel combination /iu/ were recorded for the analysis of F2, variations (F2), minimum formant frequency (F 2 min), and maximum formant frequency (F2 max). Five repetitions of diadochokinesis /pa ta ka/ were recorded. The rhythm (diadochokinesis (DDK) rhythm), speed (DDK speed), and their variation (DDK variation) as well as the intensity patterns (Intensity pattern) and their variations (Intensity variation) were analyzed.

In (2016) Thakur [24], observed clearly the changes in all the four formants during the whole menstrual cycle period but these changes are dominant in the fourth formant frequency F_4. However a significant change in F_4 observed during the menstrual phase. This further confirms that the physiological changes during the menstrual cycle are reflected in speech. Other notable changes in formant frequency values were observed on day 9, 10 and 26, which the patient had mentioned as emotional distress due to external factors. For this purpose the author collected voice samples of five patients lying in the age group of 20 to 23 years. Each patient had to utter the 52 alphabets of the Hindi character set for a period of thirty days. Then Data was filtered and utterances were separated using Goldwave. Formants were obtained using PRAAT and plotted against days in MATLAB. Vowel triangles per day were also plotted for each subjects. By all the observations we say that hormonal changes during menstrual cycle alter the quality of speech.

In 2011 Trivedi [25] collected the sample of Adult female and then applied wavelet transform for the feature extraction from the speech signal, higher recognition rates if the features are extracted properly. A small set of prescribed vocabulary words spoken is investigated as the problem of speech recognition. Wavelet transformation (WT) features used as a new method of speaker independent world recognition. There results are the modifications of previous methods which are applied for speech recognition. The number of levels of wavelet decomposition and the type of decomposition are different from the previous methods applied for speech

recognition. They did the whole process step by step and found the results. Firstly they apply preprocessing of the speech signals in which the first step is the Voice Activation Detection (VAD) and segmenting the speech signals accordingly. Then the second step of preprocessing was denoising of the sample signals. After denoising the signal they performed frame blocking and windowing then wavelet feature extraction as next step. Recognising module is their last step by which they recognised the words.

3 Discussion:

Finally all observations above shows that, there must be a relation between female hormonal changes and voice production. The female life cycle is actually moving around the systematic changes in 4 Key hormone and the voice analysis based on voice parameters like pitch, intensity, formants, shimmer, jitter, maximum phonic time etc.

Many authors like C¸elik [7], Pavela Banai [18] observed that the voice of women who uses any type of oral contraceptives, does not changes with the hormonal fluctuations. In other words we can say that there is no impact of hormonal changes seen to be on the voice production of oral contraceptive users. They also gave the result that the minimum pitch is highest in late follicular phase, average intensity is lowest in the lutial phase and higher harmonic to noise ratio in the menstrual phase. Similar result is given by Fischer [10] and Tatar [23] with the result that women speak with higher fundamental frequency in the high fertility compared to low fertility period. According to them in a speech sample the value of fundamental frequency increases and then dropped significantly during ovulation. All the analysis were held on the free speech as well as on sustained vowel sample. Also Tatar [23] compared the normative values of recordings of some specific vowels in all the faces and found some effective difference between them also compared the phonemes of different languages in all menstrual cycle phases and again found some effective difference between them. Similarly Mary Gorham-Rowan, found significant effect of day of recordings on f_0, SFF etc.

The results given Celik [7], Pipitone and Gallup[17] and Fischer [10] couple with the mixed finding in previous studies, suggest that vocal changes in relation to hormonal fluctuations are subtle, at least during vowel production. Further study should explore voice indefined social context and with more free-flowing speech. Pavela [18] and Tatar [23] also observed in their study that during the pre menstruation period, mean Jetter %, shimmer % and harmonic to noise ratio values were significantly higher than those in other phases of the menstrual cycle.

4 Conclusion:

Wavelets proved to have both strengths and weaknesses in analysing voice. The result shows that the wavelet transform can be effectively used for the extraction of features for speaker independent. The result shows that the wavelet transform can be effectively used for the extraction of features from speech signal analysis. Wavelets

are generally able to distinguish between low frequency larger amplitude and high frequency lower amplitude spectral components.

In the adolescent female the voice phono-articulatory parameters like intensity, pitch formants and harmonic-to-noise ratio (HNR), modulated by the fluctuations in sex hormones in both follicular and lutial phase of the menstrual cycle period. As a result in the analysis of gynaecological, physiological and psychological status of adolescent female it is necessary to identify phono-articulatory parameters.

In view of the above discussion we found that the hormonal fluctuations in the whole life cycle of a female impacts vocal folds function not only in naturally cycling women but sometimes in users of hormonal contraceptive and professional voice uses also, where the Wavelet transform play a very important role for analysing voice signal. There were many receptors found in vocal folds for sex hormones, which plays a very important role to create the changes in voice during pre-menstrual, menstrual and post menstrual phases. But in some cases there is no impact of hormonal changes seen in contraceptive users. So it is not possible to make any strong conclusion about whether voice production is directly related to fertility status.

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