Preliminary Measurements of Voice Parameters using Multi Dimensional Voice Program

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***Abstract*— Voice plays a major role in speech and communication. Characteristics of a "normal" voice should include a good quality, appropriate balance of oral and nasal resonance, appropriate loudness, and habitual pitch level suitable for the age, size and sex of individual and proper voice inflections. The aim of this study is to analyze the voice characteristics in young people. The comparison is conducted by using subjective and objective methods. The sample of the study consisted of ten males and ten females, aged 19-30 years, with no voice pathology. Acoustic analysis was performed in Multi-Dimensional Voice Program (MDVP; Kay Elemetrics Corporation, Lincoln Park, NJ) and included the voice recordings of sustained vowels /a/, /e/, /i/, /o/, /u/. For subjective assessments were used the laryngoscopy assessment for vocal cord function and the Voice Handicap Index scale (VHI), VoiSS scale and Buffalo scale. The score of each scale ranged within normal limits and the findings of laryngoscopy were normal for all participants. In addition, the maximum phonation time (MPT) and the ratio «s/z» evaluated and revealed no abnormalities. The analysis of the results from MDVP brought upon significant correlations between the sexes. More specifically, the mean fundamental frequency F0 for all vowels were significantly higher in women than men (p<0,001). However, the parameters of % jitter /i/ and NHR /a/, /e/ showed significantly higher values in men than women with p=0,029, p=0,006 and p<0,001. Finally, the value of VTI /a/ parameter showed a significant difference in men compared to women (p=0,035). In conclusion, the parameters % jitter /i/, NHR /a/, /e/ and VTI /o/, showed higher value in men and only the value of F0 parameter displays greater value on women.**

***Index Terms*—Voice analysis, voice parameters, MDVP, sex comparison.**

I. INTRODUCTION

In speech and communication voice has a central role. Senturia and Wilson [1] stated that a 'normal' voice should have a good quality, appropriate balance of oral and nasal resonance, suitable intensity and usual tone depending on the individual's age, weight and sex. Voice analysis is performed with specific software tools. Widely used voice analysis programs include Multi-Dimensional Voice Program (MDVP), Doctor Speech, Praat and Visi-Pitch, which are used among others for finding the regulation of voice data, dysphonia, as well as the vocal deviations in pathological populations such as patients with asthma [2]-[8].

Precisely, MDVP, initially developed by Kay Elemetrics for CLS 4300 model, allows detailed, quantitative voice analysis over 33 voice parameters that enable evaluation of fundamental frequency, amplitude, diplophonia, spectral energy balance as well as, detection of any abnormality in loudness [9]. MDVP has been widely used in literature, as many studies have been conducted in normal and abnormal population, aiming to assess changes in cancer patients voice after laser surgery or radiotherapy [10], [11], populations with different hearing threshold [12], patients with recurrent respiratory papillomatosis [13] and patients after septoplasty [14]. Furthermore, vocal characteristics' influences have been examined in patients before and after endotracheal intubation [15], in group of patients with benign vocal cord mucosal disorders [16], in children following laryngo-tracheal reconstruction and cricotracheal resection surgery [17]. MDPV has also been used in additional disorders such as, Parkinson's disease [18], [19], hyperfunctional voice disorders [20], asthma [21], unilateral paralysis, bladder [22], laryngeal disorders such as keratosis, leukoplakia and trembling, polyps, Reinke's edema, nodules and spasmodic dysphonia [22]. Still, changes on the voice have been investigated by MDVP in euphonic patients [9], at an early stage of smoking in young adults [23] as well as, in geriatric population [24].

The most commonly studied parameters in literature regardless the software used [5], [21], [25], [26] are:

A. *Mean Fundamental Frequency* (Fo), which refers to the average of all fundamental frequency values of vocal cords vibration [23]. Measurement of fundamental frequency reflects vocal cords vibration rate and compares the levels of the voice height between the same or different persons.
B. *The frequency deviation range (Jitter)*, which refers to vocal cords' vibration abnormities, is located on time and therefore to the vibration frequency [27]. Consequently, jitter is the variation of the glottal period deviation or else the frequency variation from a successive period to the next [24], [28]. Jitter percent (% jitter) gives an estimate of the tone period variability within the analyzed voice sample and represents the

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relative evaluation of the period to period (very short) variability [24].

C. *Deviation of amplitude variation (shimmer)*, refers to the abnormalities in the amplitude of vocal cords vibration [23]. Vocal chords' tumors or lack of nervous audit could influence their stability [27]. Shimmer percent (*% shimmer*) provides an estimation of the amplitude variation to the peak-to-peak within the analyzed voice sample and represents relative evaluation of the period-to-period (very short) variability of the peak-to-peak amplitude [24].

D. *Peak-Amplitude Variation (vAm)* gives the relative standard deviation of peak-to-peak amplitude, reflecting the very long term amplitude variations within the analyzed voice sample [23]. Some authors consider the analysis of amplitude variation parameters most important factors in determining the severity of voice disorders [29].

E. *Noise to Harmonic Ratio (NHR)* is the ratio of non-harmonic energy (noise) in the range 1500–4500 Hz to the harmonic spectral energy in the range 70–4500 Hz [24]. NHR provides a general evaluation of noise presence in the analyzed signal (such as amplitude and frequency variations, turbulence noise, subharmonic components or voice breaks) [23]. Noise is the lack of periodicity in vocal cords vibration, which can occur either in the entire range of voice or in specific frequency bands [27]. Normal voices have low noise levels, and abnormal high [24].

F. *Voice Turbulence Index (VTI)* refers to a regular variation of the fundamental frequency or voice amplitude [30]. Typically, this variation is between 3 and 5 Hz with respect to the average fundamental frequency [27]. Voice Turbulence is related to changes in controlling muscles used during vocalization. It is not related to the pathology of vocal cords, implicating the central nervous system for improper operation [27]. VTI parameter presents the ratio of the non-harmonic energy in the range 2800–5800 Hz to the harmonic spectral energy in the range 70–4500 Hz [23]. This parameter measures the relative energy level of high frequency noise and mostly is correlated with the voice turbulence due to incomplete or loose adduct of the vocal cords, causing vocalization air escape into the voice signal [23], [31].

Little research has been performed worldwide for voice analysis between men and women and with MDVP software. The aim of this study is to measure voice parameters in young people's vocal samples, male and female, with normal phonation, which was subjected to aerodynamic, perceptual and acoustic measurements. This is a case study for Greek population. MDVP was chosen for its reliability as a tool in research and in clinical application, in an effort to obtain regulatory data for system analysis [10]-[17], [32], [34], [35].

II. MATERIALS AND METHOD

A. *Sample*

A total of 20 Greek participants (10 male and 10 female), aged 19-25 years (M=24,06, SD=1,81), who were undergraduate students of the Department of Speech and Language Therapy, Technological Institute of Epirus, voluntarily participated in the present study was randomly chosen from a wider population in order to analyze their voice characteristics by MDVP software. This sample, included only subjects that did not i) smoke, ii) have an allergy, iii) have a common cold during the examination and iv) suffer from a serious disorder that can affect voice control.

In order to exclude any disturbance affecting vocalization, information was gained from medical and socio-environmental history questionnaire [36]. Also, orofacial examination was performed to exclude potential structural and functional abnormalities. All evaluations, that took place in sample collection, are listed in detail above.

B. *Acoustic estimates*

Recordings were accomplished according to Nicastri et al. [9], in a room where background noise did not exceed 30 dB and microphone distance to subject's mouth abstained 15 cm with 45^{o} angle from each participant. 4300 B Kay Computer Speech Lab (CSL) was used for voice recording with SM48 Shure-Prolog microphone, whose saturation had been adjusted to 6/9 of CH1 channel. Voice sample is composed of the five sustained vowels /a/, /e/, /i/, /o/, /u/ and their analysis has been accomplished at 3.8 recording seconds. Each subject had the opportunity for three phonation tests before recording, so the sample was out of intensity or frequency changes. Analysis was achieved by 5105 MDVP software, 2.3 edition and the signal was digitized at 50 kHz sample rate for a total of 100 voice recordings.

The parameters evaluated in the analysis were *Mean Fundamental Frequency* (Fo), *The frequency deviation range (Jitter)*, *Deviation of amplitude variation (shimmer)*, *Peak-Amplitude Variation (vAm)*, *Noise to Harmonic Ratio (NHR)*, *Voice Turbulence Index (VTI)*. Recording was made by making prolonged vowels, and not with the current speech, as prolonged vowels are obtained in a more readily controlled environment and fluctuations are reduced. This strategy allows the reliable achieving of disorder parameters, and the ratio of signal total energy to the noise energy [37]-[39].

C. *Acoustic perceptual estimates*

For subjective evaluation of voice, scale of Buffalo Voice Profile was used [40], which was rated by two specific speech therapists, giving each participant a text for reading. This scale assesses the laryngeal tone, voice abuse, loudness, the tone and their interruption, ripple of voice, diplophonia, nasal resonance, nasal emission, the pitch and the overall efficiency of voice [41]. These parameters were evaluated by five-point scale (1=normal, 2= mild, 3= moderate, 4= serious, 5= very serious). Then, the participants reviewed the possible disorders of their own voice, using Voice Handicap Index (VHI), which includes 30 proposals regarding the effect of voice disorder in daily life. Scores range from 0 to 4 depending on problem's frequency (0=never, 1=almost never, 2=sometimes, 3=almost always, 4=always). In addition, the Voice Symptom Scale (VoiSS), which consists of 30 proposals regarding vocal function, was used (0=never, 1=rarely, 2=occasionally, 3=more time, 4=continuously). In both scales, VoiSS and VHI, participants with total score under 20 were considered as normal [42], [43].

D. *Laryngoscopy*

During laryngoscopy, all subjects with at least one abnormality in the following parameters were excluded: i) the morphology of vocal cords free lip, ii) glottic closure iii) symmetry, iv) regularity, vi) vibration range, vi) mucosal wave, vii) level of transverse convergence, viii) supraglottic activity ix) vocal cords motility, x) closure phase xi) existence of non-vibrating portions and xii) total glottal function. All reported parameters were scored as: 0 if there was no disorder, 1 when there was little disorder, 2 moderate disorder and 3 serious disorder. The test was considered as abnormal in subjects with at least one defect in one of these parameters. For laryngoscopy, 70-degree angle rigid endoscope (Karl Storz, Tuttlingen, Germany), a camera (Karl Storz telecam DX pal 2320), video tape recording apparatus (SVO 3500 MD Sony Corporation, Tokyo, Japan) and a color screen (Sony Corporation Sony Trinitron).

E. *Aerodynamic measurements*

Maximum phonation time (MPT). MPT refers to the maximum retention period of tone with a continuous exhalation and is related to measuring the voice control ability and voice ventilator support [27]. MST determination was performed by measuring the vowel duration /a/ that produced in a comfortable frequency level and voice pitch after a deep breathing [27]. The procedure was repeated three times. Giving appropriate instructions to the participant, recording with the longest duration was considered as MPT. According to Kent, Kent and Rosenbek [44], MPT value for adult men is M=25,89 with SD=7,41 and for adult women is M=21,34 with SD=5,66.

«s/z» ratio. Boone et al. [45], as extension of the maximum time phonation measurement, argued that people apart from appropriate respiratory support, should have also normal larynx, which is evidenced by phonation maintenance of the /s/ and /z/, wherein their ratio will yield a result close to 1. A result up to 1.4 testifies vocal cords disorder. Patients invited to produce /s/ and /z/ with the longest duration that could, having diaphragmatic breathing. This procedure was repeated three times and the measurement with the longest duration was recorded.

F. *Statistical analysis*

Statistical Analysis was performed by IBM SPSS 23.0 (SPSS Inc., Chicago, IL). Independent Sample t-test was used to calculate the averages of each group for each vocal parameter that were analysed for each of the vowels.

For all the parameters tested, a power analysis was performed. Power analysis was performed by the Gpower 3.0 software. Literally acceptable is the power that is > 0.8.

III. RESULTS

A. *Perceptual estimates*

Results of both sexes, regarding the perceptual scale estimates of voice, are presented below. More specifically, the results were:

i. Buffalo (men: M=0,2, SD=0,63, women: M=0, SD=0),
ii. VHI (men: M=0,1, SD=0,32, women: M=1,9, SD=5,67),
iii. VOISS (men: M=0,6, SD=1,9, women: M=3,1, SD=5,95).

B. *Aerodynamic measurements*

MPT: The phonation maximum duration mean in men was M=23,10 and SD=3,542. Similarly, women had a mean value M=17,00 and SD=1,333.

«s/z» ratio: The mean of «s/z» ratio for men was M=0,98 and SD=0,19 and for women was M=1,06 and SD=0,14.

C. *Acoustic estimates*

Measurements of *Fundamental Frequency* F_0 was statistically significantly higher in women compared to men for each vowel (p<0,001). In detail, F_0 /a/ for men was M=125,11/SD=14,86, while for women was M=226,02/SD=18,99. F_0 /e/ for men was M=128,79/SD=13,29 and for women was M=234,04/SD=15,52, F_0 /i/ for men was M=131,59/SD=17,73, while for women was M=259,76/SD=54,64, F_0 /o/ for men was M=124,53/SD=11,56 and for women was M=233,57/SD=25,86, F_0 /u/ for men was M=129,76/SD=13,80, while for women was M=252,09/SD=33,12. In Figure 1, F_0 parameter comparison for all vowels (/a/, /e/, /i/, /o/, /u/) between two groups, was presented.

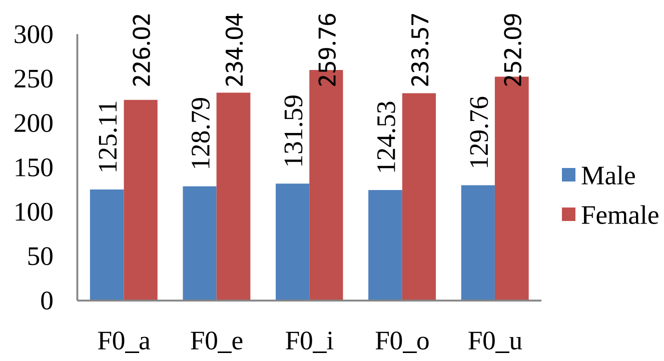

Figure 1: MDVP F_0 comparison of all vowels between male and female

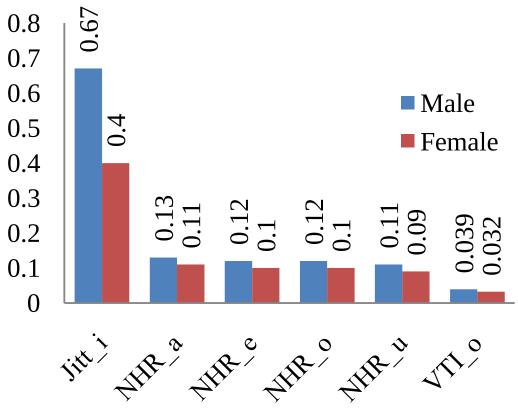

Figure 2: Comparison of MDVP parameters between male and female

The % jitter /i/ value was higher in men (M=0,67/SD=0,27) compared to women (M=0,40/SD=0,22), p=0,029. The % jitter /a/, /e/, /o/, /u/ values showed no statistically significant differences between the two sexes.

NHR /a/ parameter value for men (M=0,13/SD=`0,01) was statistically significantly higher (p=0,006, compared to women (M=0,10/SD=0,01), p<0,001, as NHR /o/ has higher value in men (M=0,12/SD=0,00) compared to women (M=0,10/SD=0,01), p<0,001. Furthermore, statistically significant trend for NHR /u/ (p=0,053) parameter was occurred. Only NHR /i/ value showed no significant difference between groups.

Finally, VTI parameter of /o/ vowel has a statistically significant difference (p=0,035), men had higher value (M=0,03/SD=0,00) compared to women(M=0,03/SD=0,00). VTI /a/, /e/, /i/, /u/ values showed no significant difference between two sexes.

However, there were no statistically significant differences between two groups for % shimmer /a/, /e/, /i/, /o/, /u/ and VAM /a/, /e/, /i/, /o/, /u/ parameter values. The statistically significant acoustic parameters distribution was presented in Table 1, while comparison of two sexes in those parameters was presented in Figure 2.

Table 1: ***% jitter, NHR, VTI male-female comparison.***

Parameters	Mean Male/Female	SD Male/Female	Sig. (p)
% jitter_i	0,67/0,40	0,27/0,22	0,029*
NHR_a	0,13/0,11	0,01/0,01	0,006*
NHR_e	0,12/0,10	0,01/0,01	< 0,001*
NHR_o	0,12/0,10	0,00/0,01	< 0,001*
NHR_u	0,11/0,09	0,02/0,02	0,053*
VTI_o	0,03/0,03	0,00/0,00	0,035*

*statistical significant p<0,05

D. Power analysis

In all cases of results that statistically significant difference was found, the analysis showed that the control power was 0.8 or higher and only a few are close to 0.7. The power analysis was quite low (< 0.8) for the non-statistically significant difference results.

IV. DISCUSSION

The aim of the present research was to study the vocal sample analysis of young adults, male and female, with normal phonation, which was estimated based on aerodynamics, perceptual and acoustic measurements, but also by means of laryngoscopy. Furthermore, values between male and female were compared for vocal parameters recorded by MDVP software, since little research has been conducted worldwide, and especially in Greece, regarding regulatory values of the two sexes vocal characteristics. Upon analysis, mean fundamental frequency (F_0), frequency deviation range (% jitter), deviation of amplitude variation (% shimmer), Noise to Harmonic Ratio (NHR), Peak-Amplitude Variation (vAm), and Voice Turbulence Index (VTI*)* were studied. Participants studied for the research were young adults of both sexes, with no pathological findings in detailed history, in orofacial examination, in aerodynamics [44], [46] and in perceptual measurements [40], [42], [43].

The results of this study, after vocal analysis performed by MDVP software, showed, concerning fundamental frequency F_0, statistically significant higher rates in women compared with men for all vowels (p<0,01). These findings are consistent with the literature [21], [23], [24], [47]. This fact suggests that vocal cords vibration rate is faster in women than men [27]. In addition, levels of voice height, which indicate the psychological trait, is higher in women than men [48].

Regarding % jitter value of vowel /i/ is greater in women group compared to men, p=0,029. This finding demonstrates variation in vibration time of vocal cords, as men have short intervals compared to women [21]. The finding that women have higher jitter in some vowels is in agreement with a recent study by Brockmann et al. [47], but also by a series of earlier studies [24], [49], [50].

Another parameter, which showed a statistically significant difference between genders, was NHR of vowel /a/ (p=0,006). NHR shows greater value for men than for women and this is in agreement with other studies by Deliyski [24], Dogan et al. [21] and Gonzalez and Carpi [23]. However, NHR showed a statistically significant difference for vowels /e/ and /o/, with men showing greater value (p<0,001). Also, an important trend occurred for the vowel /u/, p=0,053, which could be confirmed if the participants sample was larger. Therefore, we conclude that men have more noise information on the quality of their voice and thus women have better vocal cords coordination [25].

The last parameter, showed a significant difference between the two groups, was VTI of vowel /o/, p=0,035, whose value is higher in men compared to women. Nevertheless, this parameter has been only studied for the vowel /a/ by other researchers. Although the results showed no statistically significant difference for the vowel /a/, the values for both genders coincide with those of other studies [21], [23], [24]. Therefore, men's group while trying to maintain a tone at a fixed frequency, makes a slight loosening in vocal cords adduction [31], which, however, takes place within the normal range, according to MDVP radial shape results.

In the present study, % shimmer values showed no statistically significant difference between the two groups, with values to be higher in men than women. These results are consistent with a variety of studies [21], [24], [47], [49]-[51], but contradicts the findings of Gonzalez and Carpi [23]. Additionally, VAM results showed no statistically significant difference between genders, although corresponding results by Gonzalez and Carpi [23] show lower values for men compared to women.

Differences found between two genders, not demonstrate any pathology. In contrast, the actual voice contains irregular components which may occur due to chaotic nature of laryngeal mechanism [52]. Human voice acoustics are presented as a result of periodic impulse filtered by glottis, vocal tract and lips, resulting to modifications arising from fluctuations of vocal tract resonance, known as filter action [53]. Furthermore, according to the physical linkage hypothesis, there is a correlation between vocal spindle and laryngeal movement. Studies concerning the location of hyoid-larynx complex [54] or head and tongue [55], showed correlations with changes in fundamental frequency as well as, in jitter and shimmer values. Therefore, a voice without abnormalities is not perceived as human, so it introduced an abnormality in tone within the permissible limits [56], [57], which is differentiated into two genders due to different anatomical larynx design [58].

Findings of the present study emerge from limited participants sample but sufficient to bring out qualitative differences between men and women within this age spectrum. In contrast to our research, the majority of existing studies used recording and analysis of vowel /a/, as it is easy to imitate (e.g. the articulatory movements are easily visible and understandable) regardless innate language, linguistic competence or health problems [47]. Nevertheless, it is a fact that little research has been performed worldwide, as well as for Greek population, for voice analysis between men and women, particularly with MDVP software. For this reason, the results of this study were compared with corresponding results of age equalized subjects by control groups from other surveys of the literature, that have used both MDVP program and other voice analysis software (Praat and Visi-pitch). Nonetheless, it is widely accepted that comparison between different recording and voice analysis tools presents difficulties [59]. Therefore, there is an urgent need for more comparative research between the two genders with the use of this program [47], including larger participants sample and recording of all vowels. Another proposal for future research would be the extensive use of MDVP software on large number of laryngeal pathologies in all age groups and to compare the results with those of other voice analysis software.

V. CONCLUSION

In conclusion, the results of our research on voice analysis in normal young population, revealed statistically significant differences between the two sexes. Women showed higher value of the mean fundamental frequency F_0 in all vowels than men. However, % jitter /i/, NHR /a/, /e/, /o/ and VTI /o/ parameters, showed higher value in men. Although the findings of this research emerged from a limited participant sample, however, it proved sufficient to bring out qualitative differences in voice between women and men in this age spectrum. For future research, more comparative research between two genders using MVDP program is suggested, including larger participants sample and registration of all vowels. Moreover, extensive use of MDVP software deemed necessary in a multitude of laryngeal pathologies in all age groups, as well as, comparison of these results with those of other voice analysis software.

CONFLICT OF INTEREST

Neither of the authors had no conflicts of interest during the development and publication of this paper.

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