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Original Article

Acoustic Parameters in Persian-Speaking Patients with Dysphonia

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ABSTRACT

Background & Objectives: Studying voice acoustic parameters in vowel production is a crucial component of every standard voice evaluation. Voice Analysis is non-invasive. Nowadays, computerized Voice Analysis is growing rapidly. Therefore, understanding acoustic parameters in healthy and unhealthy individuals is more significant than before. This research is a step toward boosting our knowledge about voice acoustic parameters. The main purpose of this research is to study acoustic characteristics in dysphonic and healthy Iranian individuals.

Methods: The current study was descriptive-analytic. Vowel Analysis was conducted through Praat software. Voices of 50 dysphonic patients and 50 healthy participants were evaluated. The acoustic parameters included average, standard deviation, and range of fundamental frequency, jitter, shimmer, the number and degree of voice breaks, and harmonic to noise ratio.

Results: In all studied acoustic characteristics, patients' mean scores were higher than controls' mean scores, except for harmonic to noise ratio which was higher in the healthy individuals. Although, the number of voice breaks in healthy male and female population was zero, it was 1.8 in male patients and 4.4 in female patients ($P<0.05$).

jitter and shimmer in patients were dramatically higher ($P<0.05$) than their amount in healthy controls; moreover, patients' fundamental frequency range (male: 54.6±59.0, female: 78.6±68.4) was extremely broader than individuals with normal voices (male: 9.7±4.1, female: 16.2±7.3).

Conclusion: It was clarified that there are considerably significant differences in some acoustic features. These differences may be used as a foundation for diagnosis and intervention in dysphonic patients. This study illustrated that Acoustic Analysis can differentiate healthy individuals from patients. Hence, it can be used as a non-invasive, fast and accurate method.

Keywords: Voice acoustic, Fundamental frequency, Voice break, Perturbation.

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Introduction

Voice is one of the main communication tools (Nicolosi, Harryman, Kresheck, 2004). All languages use voice extensively and systematically. Voice is the product of complex multi-dimensional system, and is a combination of anatomical, physiological, and neurological systems with a complicated coordination (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007). Voice is a unique capacity which makes the speech audible and also expresses our emotions and thought. Every person has an individualized voice which not only reflects physical status of larynx (Chen et al., 2010), but it can also be affected by overall health (Saloni, Sharma, Gupta, 2013). Acoustic properties play an important role in optimal and effective communication. These parameters i.e. fundamental frequency (F0), jitter, shimmer, and harmonics-to-noise ratio (HNR) can provide some of the crucial properties of vocal health (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007; Eadie, Stepp, 2013).

In a typical voice, vocalization can be continued with ease for a period of time. However, it is not the same in some voice disorders. There may be some interruptions in abnormal vocalization which can be examined by Praat software through the following methods: (I) the number of voice breaks i.e. the number of intervals between continuous pulses; and (II) the amount of voice break defined as the total duration of voice breaks in the period of vocalization.

F0 directly indicates the vocal cords vibration which is evaluated through vowel or speech production (Zraick, Wendel, Smith-Olinde, 2005). In fact, measuring the F0 during vowel production is more prevalent and convenient. Vowel /æ/ which is an open vowel is often chosen to evaluate voice. It is also expected that women have a higher F0 than men. Three factors determine the fundamental frequency: length, volume and tension of the vocal folds (Dehqan, Ansari, Bakhtiar, 2010). Length and volume of the vocal cords are different in two sexes, but tension can affect the frequency independently from the sex. As a case in point, a young man with Falsetto, a functional disorder, produce a high pitch voice due to the vibration of the middle of the vocal cords while there is no problem with length and volume of the vocal cords. In brief, F0 is a crucial factor which should be included in all voice assessments. However, its diagnostic value is another issue. It may be inappropriate to differentially diagnose a voice disorder just based on the F0. The following points should be taken into consideration in F0 assessing: It should be static during the production, but there are actually some fluctuations which make the vibration relatively static. This phenomenon can be investigated through the range of F0 variations and pitch standard deviation[1]. These measures are expected to be slight in a normal voice (Deliyski, Dimitar, 2001); otherwise, it is diagnosed as abnormal.

The perturbation of vocal cord vibration is also quantifiable by means of two factors: jitter and shimmer. Jitter manifests perturbation between consecutive signals of the larynx, and shimmer measures the perturbations in the signal amplitude of the larynx (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007). One of the most appropriate (practical) factors in voice evaluation is harmonicity or HNR indicating the degree of acoustic periodicity. If 99% of the energy of the signal is in the periodic part, and 1% is noise, the HNR is 20 dB[2]. A HNR of 0 dB means that there is equal energy in the harmonics and in the noise (Boersma, Weenink, 2006). This index can be used to survey the quality of voice. A normal human is able to continuously produce vowel /æ/ with a HNR of about 20 dB. Higher frequencies may have higher HNR. In contrast, vocal hoarseness reduces this amount.

Clinicians believe that considering multiple parameters in assessment is more reliable and suitable than clinical judgment based on one parameter, such as F0 or jitter or shimmer (Schindler et al., 2009; Wolfe, Martin, 1997). Voice disorders occur in %3 of adults (Boone, McFarlane, Von Berg, Zraick, 2005). Voice

[1].Praat software measures pitch standard deviation in each participant individually and reports it in voice analysis under the same term.
[2].HNR is expressed in decibel.

scientists, speech & language pathologists, and therapists devote most of their energy, talent, and time to diagnose and evaluate the severity of voice disorder. They do this by various perceptual, acoustic or physiological tools (Dibazar, Berger,& Narayanan, 2006). In other words, voice properties can be examined instrumentally or non-instrumentally. Instrumental evaluation is done through a variety of software (Finger, Cielo, Schwarz, 2009; Naufel, Grillo, Grechi, 2006). Examiner's errors do not occur in instrumental analysis and this is the priority of this kind of evaluation. The results of acoustic evaluation can easily be compared with normal population and leads to a more precise diagnosis. Nowadays, instrumental evaluation is worldwide, because of the accessibility of computers and electronic devices (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007).

For several decades these properties have been frequently examined in various languages, especially English language. However, there are only few studies on Persian speakers' voice characteristics (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007; Dehqan, Ansari, Bakhtiar, 2010; Aghadoost, Amiri-Shavaki, Moradi, Jalai, 2013), and there are actually no studies on the range of fundamental frequency, pitch standard deviation, number and degree of voice breaks in Persian language speakers. Furthermore, some studies measured acoustic features in Persian speakers and used it to evaluate the efficiency of their intervention, but unfortunately there is no published data on that (Safari, Amiri-Shavaki, Ghorbani, Izadi, 2009).

In the present research, less studied factors were taken into careful consideration and the measurement conciseness was improved by more advanced equipment such as external sound card, condenser microphone, and use of "TextGrid" (Pépiot, 2014) in order to have a more reliable results.

The main purpose of this study was to investigate the acoustic properties in dysphonic patients and their differences with normal Iranian population. Clinical intervention requires precise pre and post evaluation in order to document the patients' improvement (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007) and decide about how to continue the treatment. For these reasons, clinicians and researchers need to be knowledgeable about the vocal characteristics of their native language (Naufel, Grillo, Grechi, 2006; Wang, & Huang, 2004). In other words, the second aim of this research was to meet some parts of this requirement.

Materials and Methods

Participants

100 individuals participated in this study; half of them were healthy (34 men and 16 women) and the others were dysphonic (33 men and 17 women). The sample size was calculated based on the following formula: n=16s2/d2 (Streiner, 2013).

The inclusion criteria for the case group included: Speaking Persian language as the maternal one with the standard accent, no history of neurologic and systemic diseases, and avoidance of smoking and alcohol. The patients were selected from ENT clinic of Hazrat Rasoul Medical Complex, Iran University of Medical Sciences (IUMS). Their voice disorder and its type were confirmed by a fellowship of laryngology. Furthermore, their voice problem was ascertained by two speech and language pathologists (Naufel, Grillo, Grechi, 2006) who were expert in voice disorders. None of the patients were aphonic. Their mean age was 44.60±14.04 years. The distribution of the type of voice disorder can be seen in Table 1. Normal individuals were chosen from the employees of a company.

The inclusion criteria for the control group were similar to the other group. In addition, they should not have a history of neck and larynx surgery, or taking medication at the research period (Finger, Cielo, Schwarz, 2009). Their mean age was 40.66±11.53 years. This study was accomplished from May to September 2014.

Table 1. *The Distribution of the Type of Voice Disorder*

Etiology	Frequency	Percent
Functional	13	26.0
Neurogenic	24	48.0
Organic	13	26.0
Total	50	100.0

Speech Task and Voice Recording

The headset microphone (Unidirectional, BBS-MU-435, Hong Kong) was placed 10-15 cm from the speaker's mouth and at a 45° angle from the speaker's mouth. The microphone was previously calibrated by the sound level meter (Awan, Giovinco, & Owens, 2012).

Every examinee produced vowel /æ/ continuously for 5 seconds (Naufel, Grillo, Grechi, 2006; Awan,& Roy, 2005). The voice was recorded (Laptop Samsung - model: 300E, china) by JetAudio application with "wav" format and sample rate of 44100 KHz (Dirk, & Braun, 2011), through external sound card (Mackie ONRX Black Jack-USB, USA) (Aghadoost, Amiri-Shavaki, Moradi, Jalai, 2013; Dehqan,& Scherer, 2013). Then every voice was saved separately. All voices were recorded at 9-13 o'clock (Toran, & Lal, 2009) in a quiet room (Dejonckere et al., 2001).

Voice Analysis

Recorded voices were opened in Praat (Version 5.1.17) (Boersma,& Weenink, 2009) software (Finger, Cielo, Schwarz, 2009; Sonu, 2012), and a "TextGrid" was made for each participant. In this section, the median 3 seconds of vowel was selected (Zojaji, Mirzadeh, Nourian, Sadeghi, 2007; Felippe, Grillo, Grechi, 2006) and its "TextGrid" was saved. Then, the script (Pépiot, 2014) section was activated in Praat software. And all voices were analyzed with suitable script.

All data were categorized and analyzed statistically by SPSS17. The information included average, standard deviation, and range of fundamental frequency, jitter, shimmer, the number and degree of voice breaks, and HNR. These parameters were considered as acoustic characteristics (Dirk, & Braun, 2011; Sonu, 2012; Felippe, Grillo,& Grechi, 2006).

Statistical Analysis

The statistical analysis (K-Stest) revealed that the only variable which followed the normal distribution was the HNR. Therefore, independent t-test and Mann–Whitney tests were used to identify the mean differences in HNR and other variables respectively.

Ethical Considerations

In this study, the participants received information concerning the study, and all participants signed the informed consent before participation. They were assured that their information would remain confidential. The researchers observed all ethical issues in accordance with the Helsinki Convention.

Results

The patients' mean values were higher than normal population in all eight acoustic features except the HNR which was higher in the second group. The differences in some of the acoustic features were enormous, like the pitch standard deviation in the patients, which was 8 times higher than the controls' scores. On the other hand, there were some features which did not differ dramatically between two groups (Table 2).

The findings of this study showed that there is no significant difference for F0 between the healthy and the dysphonic subjects. The results indicated that the mean of pitch standard deviation were 2.2 in normal women and 18.3 in female patients. Likewise, it was 1.7 in normal men and 16.0 in male patients. It is obvious that the difference between two case and con-

trol groups were significant (P<0.05). Similarly, patients had a significantly broader mean F0 range than normal subjects.

Based on our findings, the amount of jitter differed significantly (P<0.05) between case and control groups. Likewise, patients' shimmers were remarkably (P<0.05) higher than shimmer in the control group. In the present study, there was a significant difference (P<0.05) in HNR between two groups.

Similarly, the number and the amount of voice breaks, differed significantly in the case and control groups (P<0.05).

Table 2. *Mean of Acoustic Characteristics in Normal & Patients Groups*

Sex	Acoustical Characteristics	Health Group		Dysphonic Group	
		Mean	St. Dev.	Mean	St. Dev.
women	F0 Ave	200.4	19.2	209.5	35.1
	Pitch Std	2.2	0.9	18.3	21.6
	F0 range	16.2	7.3	78.6	68.4
	Jitter	0.004	0.001	0.018	0.025
	Shimmer	0.036	0.014	0.074	0.049
	HNR	20.7	2.8	15.1	8.4
	No. VB	0	0	4.4	6.7
	Dg. VB	0	0	0.2	0.2
men	F0 Ave	125.6	15.9	136.1	28.3
	Pitch Std	1.7	0.7	16.0	22.7
	F0 range	9.7	4.1	54.6	59.0
	Jitter	0.003	0.001	0.019	0.025
	Shimmer	0.030	0.017	0.097	0.066
	HNR	20.2	4.2	12.0	7.0
	No. VB	0	0	1.8	3.0
	Dg. VB	0	0	0.1	0.2

Abbreviations: F0= Fundamental frequency, F0 Ave= Fundamental frequency Average, Pitch Std= Pitch Standard deviation, F0 range= Fundamental frequency range, HNR= Harmonics to noise ratio, No. VB= Number of Voice Breaks, Dg. VB= Degree of Voice Breaks, St. Dev.= Standard deviation.

Discussion

The mean of F0 in normal male and female were 125.6 Hz and 200.4 Hz, respectively. This variance is resulted from the anatomical differences. Besides, the patients' F0s (male: 136.1 and female: 209.5) were slightly but insignificantly higher than the normal population. This finding is consistent with Lowell and et al. (2012) stating that there is no significant difference in F0 between patient (MTD) and control groups. Dehghan et. al. (2010) reported a significant difference between typical men and women's mean fundamental frequencies (126.1 Hz and 214.6 Hz respectively). Similarly, Wang & Huang (2004) provided evidence on this difference. There was also a significant difference between sexes in this study. Although there is some minor diversity between these findings, but it is probably resulted from individual differences and/or the dissimilarity in analytic systems. In contrast, there is no consensus on the F0 difference between healthy and unhealthy voices. In order to reach a better judgment for F0, we need to take advantage of the data from the F0 range and pitch standard deviation. As mentioned earlier, our partici-

pants were asked to produce a vowel continuously and constantly; therefore, the F0 range was expected to be minor (Little, 2009). Baken & Orlikoff (2000) suggested 10 Hz of F0 variation in normal men and low pitch voice, and about 30 Hz of F0 variations in female voice. This range is one octave higher in healthy women. Although the range of F0 variation is so limited in the normal population, it was so broad among our patients. Previously, there had been no data on the F0 range in Persian speakers. Little (2009) verified the difference in F0 range between healthy individuals and patients with Parkinson's disease. There are also more investigations confirming this difference (Goberman,& Blomgren, 2008; Stepp, Hillman,& Heaton, 2010). The other important factor is the pitch standard deviation. The lower the pitch standard variation is, the less variation in F0 during a speech would be expected. The relationship between the speed of recovery from spasmodic dysphonia and the pitch standard deviation during speech have been known for many years (Eadie, Stepp, 2013; Goberman,& Blomgren, 2008). The difference between two groups in mean of pitch standard deviation was highly significant in this study, and from this point of view, this research was consistent with the previous ones.

As the preceding investigations illustrated, any organic, neurologic, or functional change in the larynx may alter voice and shaken its acoustic features. Consequently, the jitter and shimmer increase. They are obviously the indicator of interruption in frequency and intensity. In this survey, the amount of jitter and shimmer differs significantly between case and control groups, which is consistent with findings of Casado et al. (2001), Shao et al. (2010) and Olszewsk et al. (2011). In addition, Dehghan et al. (2010) investigated jitter and shimmer in normal Persian speakers. Their findings are slightly different from our research which is probably due to using different software packages (Batalla et al., 2014). They used Dr. Speech software which is designed for clinical work, and its accuracy in determining time period is less than Praat. Nonetheless, these two surveys are similar in their findings on insignificant jitter and shimmer differences in males and females (Awan, Giovinco,& Owens, 2012).

There was a marked difference in HNR between case and control groups. It is worth mentioning that the mean of HNR in female patients was higher than this ratio in male patients, which is likely because of their higher F0. As mentioned earlier, HNR goes up with higher frequency. Dehghan and Scherer (2013) examined teachers' voices and similar to our study, concluded that the HNR in female teachers is notably higher than HNR in the control group. However, despite of our findings, they found no difference in HNR in the male population.

The vowel can be easily produced continuously with no breaks in normal people and in normal situations. In other words, voice break in the normal population is zero (Di Nicola, Fiorella, Spinelli, & Fiorella, 2006). Hence the observation of "voice break" can be an appropriate indicator of voice disorder. The amount and number of voice breaks in our normal group were zero, unlike the patient group who obviously had voice breaks. Some researchers believe that voice breaks are one of the main characteristics of spasmodic dysphonia (Sebastian, Gowri, 2014; Dejonckere, Manfredi, 2011) and others recognize it as a diagnostic strategy for voice disorders (Dejonckere et al., 2001; Cannito, Buder, Chorna, Dressler, 2012). Consistent with our results, Nicola et al. (2006) illustrated that voice break in patients were 27, while it was zero in healthy voice.

Conclusion

In this study, some acoustic parameters such as range of fundamental frequency, pitch standard deviation, number and degree of voice breaks were investigated in Persian language speakers for the first time and their value was determined in healthy and dysphonic individuals. This study revealed that acoustic features in dysphonic patients are incompatible with normal voice characteristics, especially in jitter, shimmer, HNR, pitch standard deviation, and range of fundamental frequency. Moreover, voice break can be an indicator of voice problem. Also, this study illustrated that acoustic analysis can differentiate healthy indi-

viduals from patients. Hence, it can be used as a non-invasive, fast and accurate method. Our data may be used as relative criteria in voice assessment and intervention processes in every session. Furthermore, this data provides a valuable profile of acoustic characteristics in Persian speakers.

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Conflict of Interest Statement

Authors declared no conflict of interest.

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مقالهٔ پژوهشی

شاخص‌های اکوستیکی در بیماران فارسی زبان مبتلا به گرفتگی صدا

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چکیده

زمینه و هدف: بررسی شاخص‌های آکوستیکی صدا در واکه ها یک جزء پراهمیت از هر ارزیابی استاندارد صدا است. آنالیز صدا غیرتهاجمی است. امروزه، آنالیز کامپیوتری صدا به سرعت در حال رشد است. از این رو، دانستن شاخص‌های آکوستیکی در افراد سالم و غیرسالم بیشتر از قبل مورد توجه است. این پژوهش گامی در جهت افزایش دانش ما در زمینه شاخص‌های صدا است. هدف اصلی از این پژوهش مطالعه شاخص‌های صدا در افراد ایرانی سالم و دیسفونیک است.

روش کار: پژوهش حاضر توصیفی-تحلیلی بود. آنالیز واکه با نرم افزار پرآت انجام شد. صدای ۵۰ بیمار دیسفونیک و ۵۰ فرد سالم ارزیابی شد. شاخص‌های آکوستیکی شامل میانگین، انحراف معیار، و دامنه فرکانس پایه، آشفتگی فرکانس، آشفتگی شدت، تعداد و میزان شکست صدا، و نسبت هماهنگ به نوفه است.

یافته‌ها: در همه شاخص های آکوستیکی مورد مطالعه، میانگین امتیاز بیماران از میانگین امتیاز گروه کنترل بالاتر بود، بجز نسبت هماهنگ به نوفه که در افراد سالم بالاتر بود. هرچند، تعداد شکست صدا در جمعیت زن و مرد سالم صفر بود، در مردان بیمار ۱/۸ و در زنان بیمار ۴/۴ بود ($P < ۰/۰۵$).

آشفتگی فرکانس و آشفتگی شدت در بیماران بطور چشمگیری بالاتر از مقادیر آنها در گروه کنترل سالم بودند، علاوه بر این، دامنه فرکانس پایه بیماران (مردان: ۵۴/۶±۵۹/۰، زنان: ۶۸/۴±۷۸/۶) بسیار گسترده-تر از افراد دارای صدای طبیعی بود(مردان: ۴/۱±۱۶/۲، زنان: ۴/۱±۹/۷).

نتیجه‌گیری: تصریح شد که در برخی از ویژگی‌های آکوستیکی تفاوت های قابل ملاحظه‌ای وجود دارد. این تفاوت‌ها می‌تواند به عنوان نوعی مبنا برای تشخیص و مداخله در بیماران دیسفونیک استفاده شود. این مطالعه نشان داد که آنالیز آکوستیکی قادر است که افراد سالم را از بیماران متمایز نماید. از این رو، می‌تواند به عنوان یک روش غیرتهاجمی، سریع و دقیق مورد استفاده قرار گیرد.

واژه‌های کلیدی: آکوستیک صدا، فرکانس پایه، شکست صدا، آشفتگی فرکانس، آشفتگی شدت، نسبت هماهنگ به نوفه